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FOURTH SERIES.

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THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXV.—*On the Gaseous Constitution of the H. and K. lines of the Solar Spectrum, together with a discussion of reversed gaseous lines;* by JOHN TROWBRIDGE.

I DESCRIBED in this Journal of July, 1902 and of December, 1902 the discovery of reversed lines in the spectra of gases when the latter are submitted to powerful disruptive discharges. In the first article I spoke of the desirability of obtaining some other material than glass for Geissler tubes in order to determine if any of the lines observed were due to the glass. In this Journal, December, 1902, I described some preliminary experiments with quartz tubes.

In this paper I shall show that the continuous spectra observed when glass tubes are employed are not due to incandescence of the glass walls: and also that the lines obtained by me which coincide closely with the calcium lines at wave lengths 3968 and 3933—H.H. lines of the solar spectrum, are not due to calcium, but are true gaseous lines. The great H. H. lines therefore of the solar spectrum, although being a composite spectrum of many lines, have a basis of gaseous lines. This seems more than reasonable when we consider that the solar protuberances are observed through the great H.H. lines, and when we also take into consideration the rarified nature of the gas and the improbability of a metallic vapor like that of calcium being projected so far from the sun's limb. Moreover I shall show that the reversed lines are due to a solarization of which the Clayden effect is merely a special case.

It was necessary in my work, to determine, in the first place, to what degree metallic electrodes influence the spectra in Geissler tubes of the length and bore which were employed by me. When long and powerful sparks are produced in air, the metallic lines due to the terminals disappear at a distance of

less than two inches from either terminal. The photograph therefore of the spectrum produced by a spark of three or four feet in length, taken at the middle of the spark, shows nothing but air lines, whatever may be the nature of the terminals. Indeed this is true even when sparks of eight inches in length are examined. The most effective way, therefore, of sifting out air lines from metallic spectra is to employ long and very powerful sparks. At one time I believed that the oscillatory nature of the discharge influenced the character of the spectra; I am now of the opinion that introducing self-induction acts by diminishing the energy of the discharge; and that the rate of oscillation has very little if any effect.

In the present paper I shall confine my attention largely to the immediate region of the H.H. lines of the solar spectrum.

In Geissler tubes, also, having capillaries not less than two inches in length, the terminals being three and a half or four inches apart, no metallic lines were observed under the conditions of my work. Indeed, to produce metallic spectra at such distances from the electrodes during the time of duration of the discharges, would demand a prodigious velocity of the metallic particles. I have made a careful study of the influence of metallic electrodes in the tubes employed by me and find no spectra due to them.

In order to determine whether the walls of the glass tubes could give lines due to calcium, I first placed aluminum terminals on a sheet of glass of the same kind as that from which the Geissler tubes were made, and having placed the glass against the slit of the spectroscope I passed powerful discharges of the same nature and energy as were employed in the study of the spectra of gases. The glass was badly corroded along the path of the discharge, showing the same corrosion which was observed in the capillary of the glass Geissler tubes.

No continuous spectrum was observed and no calcium lines. Similar discharges were passed through fifty ohms of No. 36 iron wire; the wire was barely raised to a dull red heat. A photograph was taken of ten centimeters of such wire, illuminated by the discharge from a Geissler tube placed in the same electrical circuit. The photograph showed the wire intact at the moment of the illumination of the tube. It took time to communicate sufficient heat to melt the wire. On the same photograph was shown the subsequent melting of the wire; that is, the wire is seen intact and also the two ends of the wire contorted and burning. If the walls of the capillary of the glass vessels are heated to incandescence, the time element must be large; for the gas must first be heated by the discharge and then the walls of the glass by conduction and radiation. Thermodynamic considerations make it impossible

that the walls of the glass vessels are heated to incandescence; moreover E. Wiedmann* has shown that the heat of electrical discharges in Geissler tubes has been much exaggerated. A photograph was taken of the light from a Geissler tube by means of a rapidly revolving mirror. Besides the tube and in the same circuit was a spark gap between magnesium terminals. The duration of the light of the Geissler tube was one fourth of that of the spark between the magnesium terminals in air. There was absolutely no duration of the light of the Geissler tube due to a supposable incandescence of the glass. The light in the Geissler tube arising from powerful disruptive discharges is the strongest and most instantaneous light which has been obtained and would be useful in the study of rapid motions.

If the glass is not vaporized by the discharges I have employed, the spectrum of calcium cannot be produced in the capillary of the glass vessels. A direct test of the question whether the reversed lines observed by me are due to the glass is afforded by the use of quartz vessels of which the ends were closed by metal plates, there being a complete absence of glass and previous investigation having shown that the metallic plates or terminals gave no metallic spectra. In the case of quartz the powerful disruptive sparks produced absolutely no corrosion of the walls of the quartz capillaries; and the reversed line at approximately wave length 4227 and wave lengths 3968, 3963, H.H. of the solar spectrum came out with the same intensity as in the case when glass was employed. Moreover the strong calcium lines toward the ultra-violet besides those which apparently coincide with the H.H. lines of the solar spectrum were conspicuously absent.

The reversed lines therefore which I described in my previous article and which are shown on the plates of that article are not due to calcium. These lines may arise from an electrical decomposition of residual air. It seems impossible to fill spectrum tubes with perfectly dry and pure hydrogen; traces of air must enter from the purifying and drying apparatus; and the impurities may be brought to light by powerful discharges. I have shown in a previous paper that the electrical decompositions in a tube apparently filled with pure hydrogen can produce various spectra, among them that of argon. The most promising method of obtaining pure dry hydrogen appears to be by the use of liquid hydrogen.

In this Journal for December, 1902, I spoke of a remarkable reversal of lines in the ultra-violet which were obtained by the use of quartz tubes.

Fig. 4 shows these lines with a companion spectrum of magnesium. These reversed lines apparently coincide with spark lines

* Wied. Ann., vi, 1878.

of silicon, in air; and one might conclude that the lines come from a volatilization of the walls of the quartz capillary. There is, however, absolutely no corrosion of the walls of the quartz vessel. The surface of the quartz remains limpid and clear. Fig. 3 shows the same lines, wave lengths 2882, and group from 2542 to 2507. In fig. 3 these lines are not reversed and there is no continuous spectrum. The argument of incandescent walls to account for the continuous spectrum in the case of glass tubes would require a heat of incandescence to volatilize the silicon to produce the bright lines seen in fig. 3. I have concluded that, just as in the case of the supposed calcium lines with the employment of glass tubes, these reversed lines are also due to a gas. In order to discover whether these lines can be obtained from some gaseous constituent of the air, I have studied the spectra obtained from powerful sparks in air taken from a great variety of metallic terminals. The spectra from terminals of pure platinum, electrolytic silver, and iridium show strong lines, which coincide with the dispersion I have employed, with the great H. H. lines of the solar spectrum and also with the gaseous lines I have obtained in rarified hydrogen. Terminals of aluminum, copper, iron, tin, magnesium, do not show these lines, or if at all, very faintly. The noble metals, which are least affected by the electric discharge and which are therefore used for nonoxidizable contact in electric apparatus, give these lines. Is it not probable that when the electric discharge volatilizes to a high degree the electric discharge prefers a passage through the metallic vapor—that is, when short and powerful condenser discharges are employed—and does not sufficiently heat the air to bring out certain air lines. The method of sifting out air lines from metallic spectra by observing the lines which are apparently common to these spectra and setting down such lines as air lines, is a fallacious method. Silicon is not easily volatilizable and certain important groups of lines attributed to that metal, obtained by the use of the spark in air, may be atmospheric lines. I have obtained traces of such lines which seem to coincide with the gaseous lines I obtained with rarified hydrogen in quartz tubes by employing water electrodes. These electrodes were made as follows: two iridium terminals were placed on pieces of kiln-dried wood four inches apart. The condenser spark could leap only one inch. The wood was wrapped with cotton enclosing the metallic terminals; around the cotton was wrapped chamois skin; the clear space between the ends of the wood, thus protected, was half an inch. The terminals thus prepared were soaked in distilled water. A very powerful spark was thus obtained in air: and the spectrum was entirely free from metallic lines. With these terminals it is undoubtedly true that the water vapor conducted the main body

of the discharge just as the metallic vapor does in dry air. The edges of this spark show a strong red tint and give the line spectrum of hydrogen. The center of the spark is of a brilliant whiteness. Strong bands appear in the position of the reversed lines which I have obtained with rarified hydrogen, in the quartz tubes.* There is evidently a chemistry of the electric spark in relation to the appearance of certain lines of the constituents of atmospheric air. The discovery of argon shows this. I am at present working upon this question with still more powerful sparks. The commercial employment of high voltages and great current strength should permit more powerful means in spectrum analysis than have hitherto been employed.

The continuous spectrum observed with disruptive discharges in gases occurs also when electrical discharges are obtained in distilled water and in certain other liquids. Prof. Wilsing,† G. E. Hale,‡ and Lockyer,§ have discussed the reversed lines observed under this condition. The phenomenon of continous spectrum and of reversals obtained by the investigation is, I believe, of the same nature as that observed by me in gases. The continuous spectrum is due to a sudden compression of the medium under the powerful disruptive electrical explosion, and the reversals are due to a solarization and not to a reversing layer. The reversed lines observed by me increase in intensity with repeated discharges. The action appears to be most pronounced toward the ultra-violet. This is the case also with the reversed lines observed under water.

The conclusions, therefore, of my first paper on reversed lines in this Journal for July, 1902, are confirmed by further investigation. At the basis of the great H.H. lines of the solar spectrum there are strong gaseous lines, which I believe are oxygen lines. The reversed lines which apparently coincide with certain calcium lines are not due to calcium but are gaseous.

The phenomena of photographic reversals is of great importance in the study of changes going on in the sun. The accompanying plate show the normal spectra which illustrate this article. Fig. 1 represents the gaseous lines which closely correspond with the great H.H. lines of the solar spectrum. See also fig. 3, in my article in this Journal, July, 1902.

Fig. 2 represents the spectrum of calcium in the neighbor-

* It seems probable that these lines, and also the great H.H. lines of the solar spectrum, are due to oxygen. At very high temperatures the dissociated oxygen may be free to vibrate in its own periods. It does not seem inconceivable, therefore, that many spectral lines attributed to metals may be oxygen lines.

† H. Kayser, l. c., i, p. 228.

‡ G. E. Hale, Astrophys. Jour., xv, 1902.

§ N. Lockyer, Proc. Roy. Soc., lxx, 1902.

hood of the H.H. lines. It is seen that strong lines of calcium are conspicuously absent in fig. 1.

Fig. 3 shows the gaseous lines obtained in a quartz tube

Fig. 1

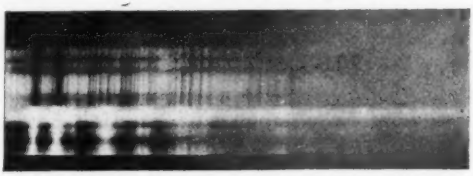


Fig. 2

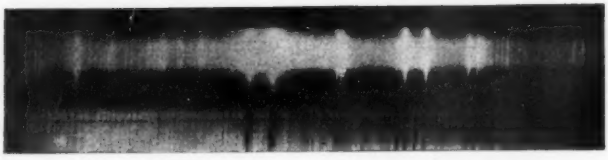


Fig. 3

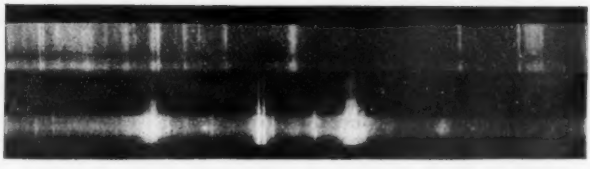


Fig. 4

filled apparently with hydrogen. A strong group of magnesium lines are added for comparison.,

These magnesium lines are the strongest lines of that metal between wave lengths 3000 and 2000.

Fig. 4 gives also the same comparison spectrum of magnesium and reversed lines of the gas contained in the quartz tube.

Jefferson Physical Laboratory, Harvard University.

Art. XXVI.—*The Boys Radiomicrometer;* by C. C. Hutchins.

The following represents the result of many weeks of work spent in the attempt to improve the radiomicrometer, invented by Boys in 1888. If one may judge from notices in the scientific journals, comparatively few have made use of the instrument since its invention. Its simplicity, wonderful sensitiveness, freedom from outside disturbance and other excellent qualities commend it highly, and were it not for the difficulty of preparing the small circuit that is its active and vital part, doubtless it would find a more extended use. Nor is it the mere mechanical difficulties of construction which are here implied; anyone with a fair degree of skill may overcome them, and having done so, it is disheartening to find one's labor in vain—as is very likely to be the case—so frequently do the troubles caused by the magnetic peculiarities of the wire forming the conducting loop make all skill of no avail.

Lewis* made more than seventy-five of these circuits before obtaining a usable one—a record of monumental patience, but hardly calculated to inspire others to begin. The experience of others does not seem to have been very different. The following instance will show how minute are the forces that come into play. A circuit was made from No. 36 copper wire cleaned with fine sand paper. It was found so strongly diamagnetic as to be quite useless. A second circuit was made from the same sample of wire, but cleaned with emery paper that had previously been rubbed upon iron. This circuit proved paramagnetic, and useless for that reason. It will, then, be readily seen how, using ordinary materials, one might spend weeks and never obtain a sufficiently neutral circuit.

If the loop be paramagnetic it sets with its plane parallel to the lines of force of the magnetic field and has a short period of vibration, and the instrument is consequently insensitive. If, on the other hand, it be diamagnetic, it sets with the plane of the loop at right angles to the lines of force. If now it be constrained by torsion of the suspension to take its proper direction, unless it be very strongly diamagnetic, it does not return at once to its position of equilibrium, but drifts back and forth without ever coming to rest, and only after some minutes or some hours returns to the position from which it was disturbed.

Many variations of the above program may be observed, but such is their general behavior as I have observed it, and it

*Standard wave-lengths in the infra red spectra of the elements, Astrophysical Journal, 1895, ii, 1.

would be mere accident or good fortune that one would secure a sample of wire yielding a circuit having a stable zero point and a period of, say, ten seconds.

Paschen* used silver wire, which he found diamagnetic, and corrected this in part by drawing it through steel plates. He obtained considerably greater sensitiveness than was obtained by Boys.

Whatever method of construction of the circuit be adopted, the fact that no available material is magnetically neutral, entirely upsets in practice any theory of the instrument that may be formed. For instance, the sensitiveness of the instrument should increase proportionally to the increase of the magnetic field in which the circuit hangs; but, inasmuch as the magnetic disturbance varies as the square of the field strength, diminishing the field strength may increase the sensitiveness; and this follows whether the material of the loop be either dia- or para-magnetic. In one instance, placing an iron rod across the poles of the field magnet increased the sensitiveness of a certain circuit eight or ten times. Lewis† found that a cast-iron magnet might be too strong. Too much care can not be taken to employ a field as weak as other circumstances will allow, the magnetic disturbances diminishing so rapidly with the field strength. These circumstances are: slight sensitiveness, for a neutral circuit, in a weak field, and a limit beyond which the weight of the circuit can not be reduced. For supposing a circuit magnetically neutral, if we employ a weak field we must employ a suspension of little torsion, and meet the increased period of vibration consequent upon the weakening of the suspension, by diminishing the weight of the circuit. This last has the advantage of removing a portion of the disturbing element, so that, in the end, the stability and sensitiveness of the circuit will depend upon how light it can be made, as well as upon the character of the material that enters into it.

I purpose now to offer a construction which, in my hands, has never failed to produce satisfactory results, yielding very light circuits of great sensitiveness and stable zero point.

Preparation of Bars for the Thermal Junction.—Two alloys are prepared,‡ first, bismuth containing 2 per cent of antimony; and the second, bismuth containing 10 per cent tin. Usually much trouble is experienced in working these brittle metals into fine bars. It is easily accomplished as follows: A quantity of the metal is melted, made very hot, a small pool poured upon a sheet of smoked glass, and a second piece of

* Wied. Ann., xlviii, 272 (1893). † Loc. cit.

‡ C. C. Hutchins, Thermo-electric heights of bismuth and antimony alloys, this Journal, xlviii, 226 (1894).

smoked glass pressed quickly upon it. In this way the metal is pressed while melted into a thin leaf. I have sometimes succeeded in producing leaves of the bismuth-tin alloy as thin as $0{\cdot}02^{mm}$. They are commonly, however, much thicker.

A sound bit of one of these leaves, if too thick, is worked down under the finger upon fine sand paper. No trouble will be found in so making a plate as thin as $0{\cdot}04^{mm}$, and no particular care is demanded. Very narrow bars may be cut from the plate by laying it upon glass, covering as narrow a portion as is desired with a second bit of glass, and cutting off the projecting part by repeated strokes of a sharp knife or graver. By this method of proceeding the bars are rapidly produced, and half an hour suffices for making a supply. The electrical resistance of these alloys is so high that they are easily made too thin; $0{\cdot}06^{mm}$ to $0{\cdot}07^{mm}$ will be found better than thinner, and bars of this thickness may have a length of 6^{mm} to 10^{mm}, and a breadth of $0{\cdot}25^{mm}$ to $0{\cdot}5^{mm}$, according to the remaining dimensions of the circuit.

The Conducting Loop.—With a view to obtaining uniformity of composition, extreme lightness and rigidity, the conducting loop is prepared as follows: Some pieces of soft brass wire No. 27 are well cleaned and silver-plated in a bath of pure silver cyanide dissolved in potassium cyanide. A weak current should be used to insure an even deposit, and the wires should be occasionally removed from the bath and rubbed with crocus-cloth. The deposit may be allowed to reach a thickness of $0{\cdot}04^{mm}$, when the wires are washed and dried.

One of these wires is now bent into a loop of the form and dimensions desired for the finished article; then laid flat and the silver coating filed away on either side. The loop is now suspended from a platinum wire in warm hydrochloric acid, and the brass soon dissolving, there remain two beautiful loops of pure silver, one from the outer and one from the inner parts of the wire. It is evident that the peculiar sectional shape of these loops gives them great lateral rigidity, so that they can be made three to five times lighter than a No. 36 wire, and retain their shape and permit of easy handling.

In the same way loops may be made of copper, by plating upon an aluminum wire, or of gold; but I have found the silver most satisfactory.

Assembling the Circuit.—Having now the bismuth and antimony bars and the conducting loops, we select a pair of the former as nearly alike as possible, and solder one end of each to a disc of thin copper foil 1^{mm} to 2^{mm} in diameter, one bar on either side of the disc and near its edge. The bars should lie just parallel. A thin scale of mica is pushed between them, the silver loop brought into place and soldered. The soldering

is the only difficult part of the whole construction, and will probably try the hand and patience of the beginner. A magnifying glass is of assistance, and a very sharp-pointed tool should be used. Of course, only the minutest quantity of solder is permissible. A solder having a low melting point is desirable, and I have found an alloy of tin, bismuth, cadmium and lead, melting at about 80°, in every way suitable.

The circuit being successfully assembled, the mica is removed, and it only remains to thin the silver loop by holding it for a moment in strong nitric acid and quickly transferring to clean water. This process may be repeated, and the thinning carried beyond the point at which the surface tension will hold the sides of the loop together when it is lifted from the water. When thus made very thin indeed, it is well washed in water and in alcohol, and completed by blackening the little copper disc with Chinese ink, or drop-black. Instead of soldering a wire to the top of the loop for attaching it to the mirror staff, I have found it better to furnish the latter with a flattened hook upon which to hang the circuit. Thus it may be readily taken off for alteration, or another circuit substituted, while in no way disturbing the suspension.

The Mirror.—The mirror is made as usual by cutting a small square or oblong from a silvered microscope cover-glass. It was after condemning as worthless several excellent circuits that I learned that the mirror was causing the trouble. The quartz suspension was very fine, and after removing the circuit from its hook, four complete turns of the fiber were required to sensibly alter the position of the mirror alone. Not all mirrors may be as magnetic as this, but when we are dealing with such minute forces too great precaution cannot be taken. A house of soft iron was constructed for the mirror to swing in, and this being done the difficulty was removed.

The Suspension.—Nothing remains now but to suspend the circuit from a very fine quartz fiber, and provision should be made in the instrument for allowing this fiber to be of any length from 10 or 12 down to 1^{cm}. It is advisable to first suspend the circuit in a glass tube or jar, away from magnets, and to test its period of vibration. If this period be less than 20 sec., the fiber is too coarse. Having found a suitable suspension, the circuit is hung in the instrument, when, if all has gone well, the period will not be greatly altered, and the circuit will be completely under the control of the suspension. In case the circuit is slightly magnetic the period will be less than the free period; but if diamagnetic, greater. However it may be, it is easy to adjust the length of the suspension to give any period desired. In one instance a fiber only 8^{mm} long gave a period

of 12 sec.—about as long as can be used unless precautions be taken to shield the instrument from temperature changes.

Condensing Mirror.—For ordinary purposes the instrument is vastly improved by placing behind the copper disc a small silver or platinum mirror about 1^{cm} diameter and the same or less focus. It is mounted upon the end of a metal plug which moves with friction in a metal tube at the back, that is, opposite the heat-receiving opening of the instrument. Heat is received through a diaphragmed tube, whose diameter may be the same as that of the mirror. The advantages of the condensing mirror are: First, it renders the instrument ten to twenty times more sensitive by increasing the effective heat-receiving surface; and, second, the sensitiveness may be instantly changed through wide limits by more or less withdrawing the mirror, the highest degree of sensitiveness corresponding to the position in which the copper disk is just at the focus of the mirror. Under such conditions of temperature change, convective currents, etc. as are found in an ordinary room, it is not to be expected that the zero point of so sensitive an instrument will remain fixed. When using a very sensitive circuit with long period, although it hung in a block of iron a kilo in weight, yet merely breathing in its direction from the distance of a meter or more gave a deflection greater than the length of the scale. I therefore surrounded the heat-receiving tube with a thick jacket of wood, then swathed the whole instrument in many yards of bunting, torn into strips, until the whole became a huge ball.

It is hoped that the above notes will be of assistance to those who may wish to construct and use this most beautiful but very troublesome instrument.

Searles Physical Laboratory,
Bowdoin College, Brunswick, Maine.

ART. XXVII. — *Meteoric Iron from N'Goureyma, near Djenne, Province of Macina, Soudan;** by E. COHEN. (With Plates II–IV.)

THE meteorite that fell on June 15th, 1900, in Soudan near N'Goureyma, north of Koakourou, in the Province of Macina, weighed 37½ kilograms and is roughly of the form of a drop or flat, wedged-shaped mass 57½^{cm} long, with its greatest width 28^{cm}, about one-third of its length. The wedge tapers towards both ends, the sharpened being 3¾^{cm}, and the blunt end 14^{cm} broad, so that the edges appear to be bulged out. This form as a whole, as well as the various scallopings and jagged projections in detail, will be made clear by reference to Plates II and III. Varying between 1 and 9^{cm} in thickness, the mass is so thin as to be bounded practically by only two surfaces which meet in a pretty sharp edge (Plate III, fig. 2): one surface (Plate III, fig. 1) being considerably more convex than the other (Plate II).

From the characteristics of both surfaces it may be concluded with certainty to be a conspicuously "oriented meteorite," of which the flatter side forms the back and the more convex surface the breast. Compared with the breast the back is characterized by shallower, larger, and for the most part elongated depressions, broader and more rounded edges, smoother surfaces, less uneven and somewhat lighter crust, sharper projecting points or tongue-shaped prominences, and coarser drift effect which is confined to the pointed end. The breast has a greater convexity; smaller, deeper and for the most part rounded cavities, with small bowl-shaped formations on the walls, producing a pock-marked appearance; darker and rougher crust; finer and more abundant drift effect, which is most sharply defined toward the thicker end; and an isolated, deep cavity on the shield-shaped part. Undoubtedly, during the passage of the meteorite through the air, the broader part was directed forward. This is shown by the projections and jagged prominences directed toward the pointed end, the orientation of the elongated depressions, the overlapping of the crust and nickeliferous iron at the edges, the course of the general drift effect and the nature of the abrasion; supposing, as I imagine, that this occurred within the atmosphere by air erosion.

The original form may, however, have been much more regular than the present one and may, perhaps, be compared to a flat oval shield whose apex is eccentric and lies near the highest point of the still remaining bulge. The position of the only deep cavity on the bulge has a like significance. It is

* This meteoric iron is now in the hands of H. Minod, Comptoir Mineralogique et Geologique, 3 Cours des Bastions, Geneva.

not uncommon to find one or several especially deep cavities at or near the apex of the anterior surface of an oriented meteorite; since, on the part of the surface farthest forward, the incandescent and greatly compressed air has the greatest erosive effect and can there produce the deepest cavities.

It may further be concluded that this shield-shaped mass with eccentric apex moved through the air inclined at an acute angle to the direction of its motion, in which position the direction of the projections and prominences on the back, as well as the general drift-effect, are more readily brought into accord. It has already been mentioned that the drift-effect appears on both surfaces; a fact which apparently has never before been observed. However, on the breast it is much more abundant as well as more regular, and is more sharply defined on the broader part: while on the back it occurs distinctly only on the tapering end. Its occurrence on both faces, and particularly its distribution, is intelligible to me only on the assumption of an inclination of the meteorite to its path; for in a position either parallel or at right angles to the path, the periphery must have encountered both the heating and air erosion in an approximately like manner, and there could scarcely have been such an unlike deformation.

Because of the slenderness of the shield-shaped body, it is highly probable that the entire mass was molten or at least much softened, so that a considerable part was brushed off, and the air, churned into eddies, could produce greater erosion and abrasion than is usually the case. The result was that the entire back, and the part of the breast to the rear, was covered with closely crowded cavities and bowl-shaped depressions. Only that part of the breast farthest forward suffered the usual, almost evenly distributed melting, without any appreciable splitting-off. Had the motion continued somewhat longer, the deformation would apparently have advanced still farther and possibly the entire remaining part of the shield-shaped surface would have vanished.

The total change of form must have been completed by a time during which the velocity of the meteorite was still sufficient for the formation of crest and drift-effect on the newly made surfaces. It must, further, have been completed within such a short period of time that a complete change of front, in consequence of a change in the position of the center of gravity, could not have taken place, since otherwise the drift-effect must have been effaced. It is not impossible, however, that a tilt occurred about an axis perpendicular to the length and lying in the median plane. In the middle of the breast there is an unusually deep cavity which, in every essential character, is distinguished from all the other depressions. If this cavity was produced in the same way as those on the back, then the

part of the meteorite in question must at some time have been likewise most exposed to the eroding action of the compressed air. The two perforations require no special explanation. Where they occur, the meteorite is so thin that the coincidence of normal flat cavities on the breast and back sufficed for their production.

A pronounced peculiarity of N'Goureyma, which one readily observes in examining polished sections, is the enormous number of small troilites and their regular arrangement, as well as their quite uniform distribution. In sections parallel to the length of the meteorite (Plate IV, fig. 1) these appear mostly as needles, $1\frac{1}{2}$ to 11^{mm} long and $\frac{1}{4}$ to $1\frac{1}{2}^{mm}$ thick; or as thick-set to elongated bars, sometimes tapering to the finest threads. They also occur in the form of hook-shaped contortions, fork-like bifurcations, ramifications, or wholly irregular forms which, in those of smaller dimensions, diminish to mere points. Whenever, in the section under consideration, there is a club-like arrangement, the thicker end always lies toward the pointed end of the meteorite, as though the troilite had been drawn out in the direction of the motion.

In sections at right angles to the length of the wedge (Plate IV, fig. 2), on the other hand, the troilite stems invariably occur in cross section, showing the greatest variety of forms. Very frequently they are rounded or, when larger, elliptical. In either case the troilites are sometimes compact, sometimes in the form of a hollow cylinder, the walls varying from 0·1 to $0{\cdot}3^{mm}$ in thickness, filled with nickeliferous iron. Occasionally, however, the latter is divided into two equal parts by a thin portion of troilite; or sundry isolated cylinders of iron occur in the troilite. Four of the latter, for example, were observed in a troilite cylinder of $5/4^{mm}$ diameter. Other sections show forms resembling crescents, horseshoes, sickles, hooks, Ts, masses shaped like clubs or tadpoles tapering to threads of $0{\cdot}05^{mm}$ diameter, and are sometimes fashioned into various strange hieroglyphics, such as occasionally appear in schreibersite, but, so far as my knowledge extends, have never heretofore been observed in the troilite of any meteoric iron.

These forms on the two sections at right angles to each other show that all the troilites are extended in the same direction and are parallel; forming an arrangement closely resembling the fluid structure of terrestrial rocks. One can best form an opinion of the entirely unusual number of enclosures, which of course are in part very small, when I state that I have counted over 150 troilites on a surface of $12^{sq\ cm}$ and that there is scarcely a surface of $0{\cdot}5^{sq\ cm}$ to be found in which they are entirely lacking. The distribution on any cross section is always pretty uniform; the total number, however, diminishes appreciably toward the pointed end of the meteorite, as though

the troilite had been crowded back through the softened mass during the flight, or worked up in consequence of their low specific gravity. It may also be especially emphasized that there is an entire lack of any perceptible association with daubreelite, graphite or schreibersite, as well as of nodules of larger dimensions, such as usually prevail in iron rich in troilite.

Schreibersite is unusually sparsely represented in these sections. In most of them it is entirely lacking, and only the largest sections, of $148^{sq\ cm}$, contained, directly under the burned crust or near it, lamellæ of which the largest was 3^{cm} long and 2^{mm} thick.

Observation of the unetched sections alone show that N'Goureyma belongs to the comparatively rare group of coarsely granular irons. The fractures marking the limits of the granules, however, as usual, are brought out more distinctly and completely by etching, which makes them broader and deeper. Isolated fractures open to a width of $\frac{3}{4}^{mm}$; others are so small as to be perceived only under the microscope. Occasionally the fractures are found to be filled up with troilite, the separation of which must have continued after the formation of the fractures, although the fluid arrangement justifies the conclusion that the main separation had occurred earlier; these granular components are bounded by irregular edges, though the majority are in general fairly isometric, with a thickness varying between $1\frac{1}{2}$ and 3^{cm}. Isolated ones diminish to $\frac{1}{2}^{cm}$. Many are elongated, especially the larger ones, which then attain a length of 7^{cm} and a thickness of 2^{cm}. In this respect the five cross sections are exactly alike. The section made from a tongue-shaped projection (Plate IV, fig. 2) appears, however, to be an individual; evidently a single granule which has been drawn out in the direction of the longitudinal axis of the meteorite; in which case, because of the slenderness of the projection, contraction fractures (perhaps parallel to the section) would certainly not be at all obvious.

Etching develops glistening plates (Plate IV, figs. 1 and 2), the arrangement of which is suggestive of Widmanstätten figures. Under the microscope, however, one sees that there are really no connected lamellæ at all, but that tiny spangles or granules, better reflecting than the remaining nickeliferous iron, collect in indistinctly defined and small elongated clusters, arranged in more or less connected rows which intersect in groups. At any rate, there is nothing perceivable under the microscope which could suggest the kamacite blades and their taenit fringes found in normal octahedrite. The remaining nickeliferous iron, which perhaps is plessite, appears to predominate in places and then again to be less prominent; always, however, forming a coherent body like the nickeliferous iron of compact ataxite.

Such peculiarities of structure are unknown to me in any other meteoric iron. It seems to me quite plausible that this was originally a coarsely granular octahedrite, like Zacatecas, which in consequence of its very flat form softened throughout its mass, perhaps to the melting point, as it entered the atmosphere. In the subsequent rapid cooling there was not time enough for a normal crystallization—formation of octahedral lamellæ. Alloys rich in nickel could not unite so as to form symmetrical taenit lamellæ; but, during precipitate crystallization, separated into the finest spangles which in their habit arranged themselves so as to be oriented parallel to the octahedral planes, while the remainder uniformly solidified to a compact plessite-like nickeliferous iron.

This assumption of the softening or melting of the entire mass of the meteorite, however unusual, is supported by a large number of phenomena which, up to the present, have never been observed in any other iron. Among these peculiarities are:—the fluid arrangement of the troilite; the absence of larger nodules, despite the unusual richness in sulphide of iron; the lack of an alteration zone, along with the possession of a completely fused crust; the tapering and tongue-shaped projections, extended in the same direction; the pointed, wedge-like shape; the unusually varied and in part bizarre relief of the anterior surface; the perforations, which cannot be attributed to the melting out of accessory ingredients; and the increased richness in troilites toward the part of the meteorite which was rearmost in the course of the flight.

I consider that these phenomena prove N'Goureyma to be a member of the Zacatecas group, which was remelted during its passage through the air, and may be considered as a sort of appendage to this group. The unusual richness in sulphide of iron, moreover, could have had an influence on the disturbed crystallization, just as in Zacatecas, rich in troilite, the octahedral structure is less complete than in most of the normal octahedrites.

The analysis which I have made gave the following results:—

Fe	89·28	Nickeliferous iron	97·28
Ni	9·26	Schreibersite	0·32
Co	0·60	Troilite	1·75
Cu	0·04	Daubreelite	0·30
Cr	0·11	Lawrencite	0·02
S	0·77	Chromite	0·09
P	0·05	Decomposed silicious grains	0·24
C	0·04		
Cl	0·01		100·00
Chromite	0·09	Specific gravity is 7·672	
Residue	0·24		
	100·49		

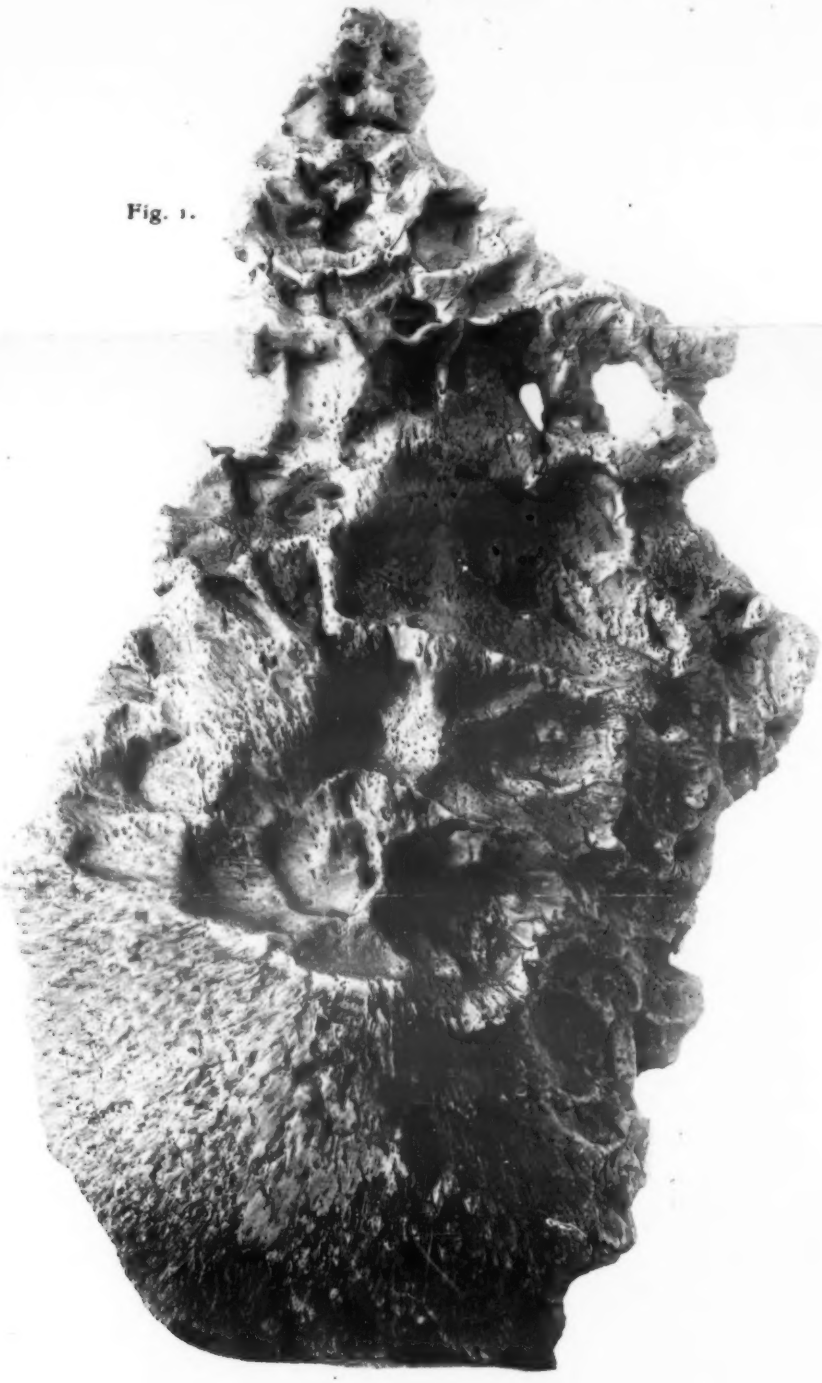
Greifswald, Germany.

About 2/5 nat. Size

Meteoric Iron from N'Goureyma

(The Property of the Comptoir minéralogique et géologique suisse, Geneva)

Fig. 1.



About 4/11 nat. Size.

Fig. 2.

About 2/5 nat. Size.

Meteoric Iron from N'Goureyma

(The Property of the Comptoir minéralogique et géologique suisse, Geneva)

Fig. 1.

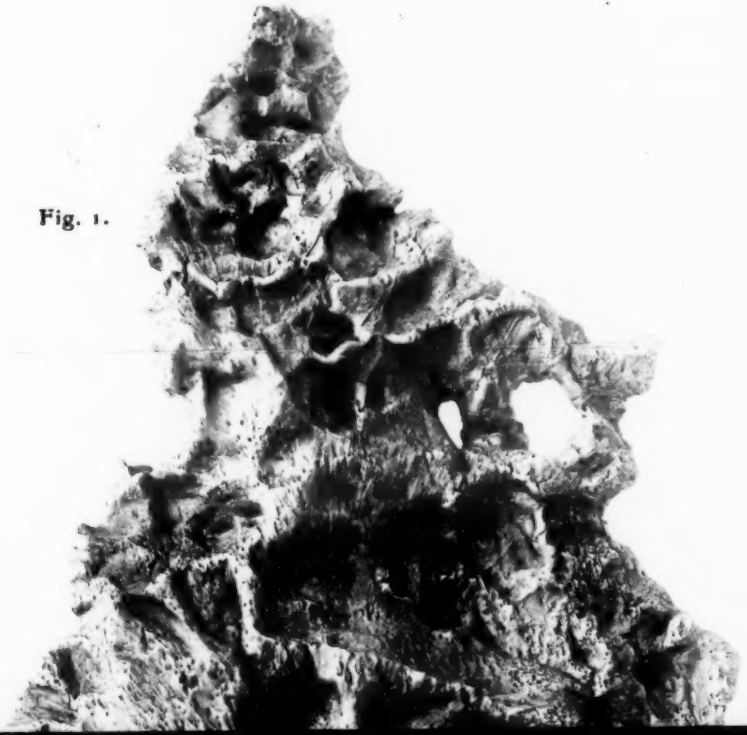
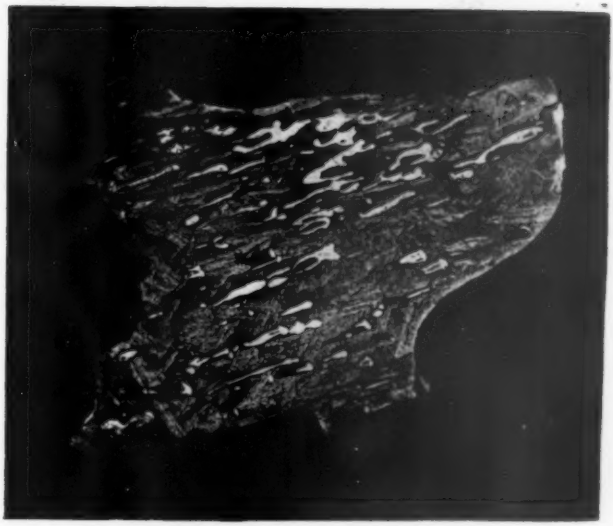


Fig. 2.

Fig. 1

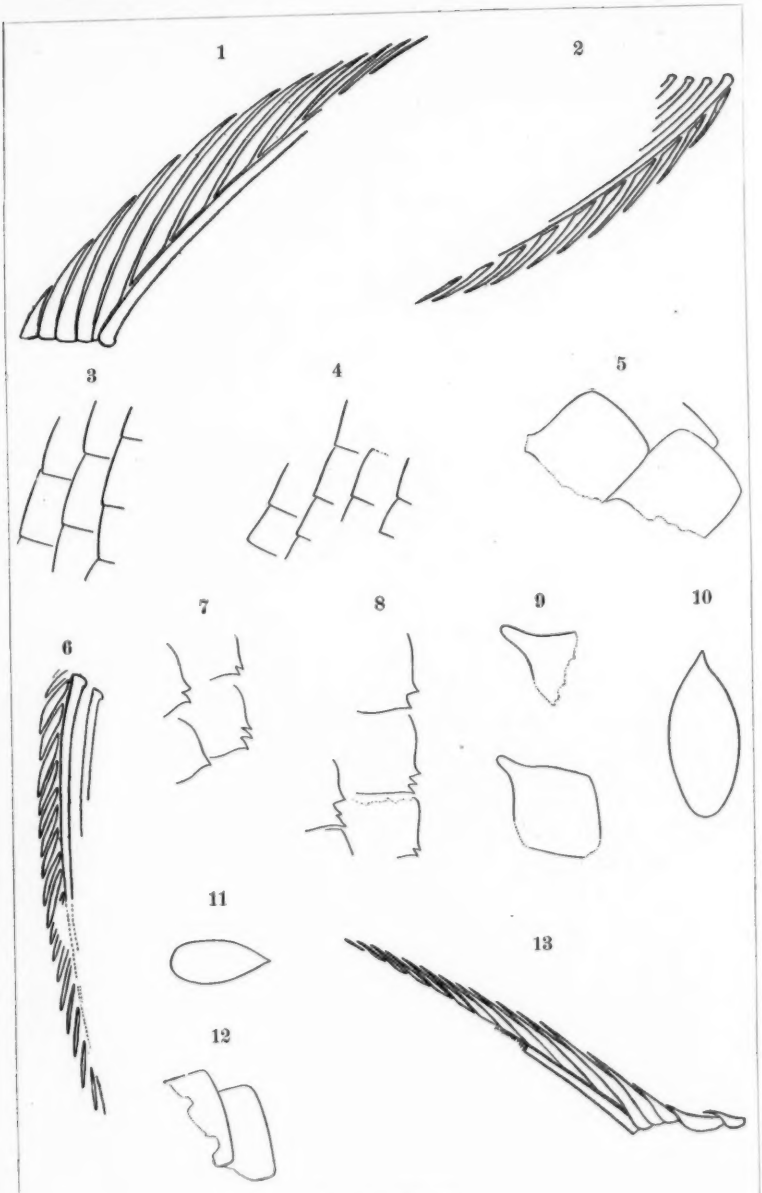
16/11 nat. Size

Fig. 2



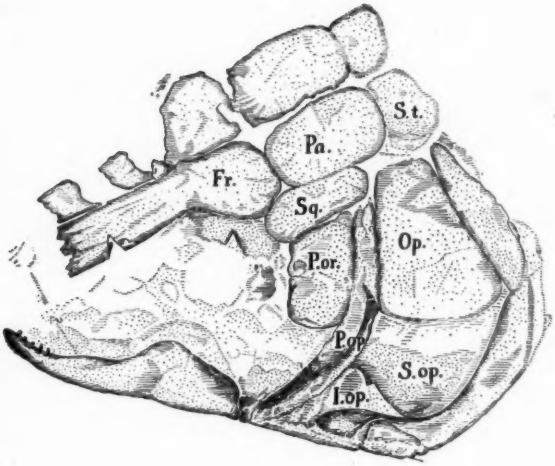
4/3 nat. Size

Meteoric Iron from N'Goureyma



TRIASSIC FISHES.

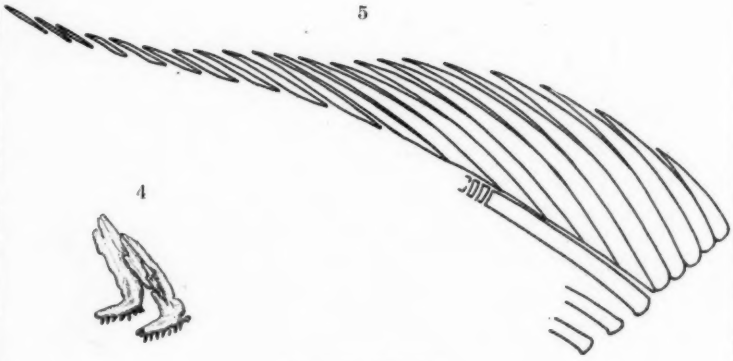
1



2

3

5



4

TRIASSIC FISHES.

ART. XXVIII.—*Notes on the Collection of Triassic Fishes at Yale;* by G. F. EATON. (With Plates V and VI.)

IN 1870 the collection of Triassic fishes made by Messrs. W. C. and J. H. Redfield, and generally known as the "Redfield Collection," was presented to the Yale Museum, with the understanding that it should be arranged and placed on exhibition as soon as opportunity served. The gift was acknowledged in the annual report of the Sheffield Scientific School, 1870–71; but for various reasons most of the specimens remained unexamined in the store-rooms of the museum for nearly thirty years. Meanwhile, good material of the same geological age, received from other sources, has greatly enhanced the value of the Yale collections.

Semionotus.

In preparing these Triassic fishes for exhibition, an attempt was made to follow Prof. Newberry's classification, as proposed in his monograph on the Triassic Fishes and Plants.* His arrangement, however, was not found entirely satisfactory. Especially was this the case in regard to the genus *Semionotus (Ischypterus)*, under which some of the specific definitions are uncertain guides in identifying specimens, because of the lack of characters offering any real contrast between the different species named. Fortunately most of Prof. Newberry's types are preserved in the Yale University Museum and in the Columbia University Museum. After a careful study of these and of all other accessible material, the present writer has been enabled to state additional characters to some of the species described in Prof. Newberry's work; while, on the other hand, it still seems advisable to leave many forms in the doubtful list to which they were relegated by Dr. A. Smith Woodward.† Indeed it appears probable that Prof. Newberry's enthusiasm led him to describe more species than are now warranted by the better and larger collections available for study. Well aware of the difficulties he encountered in classifying such imperfect and indistinctly preserved material as the American Triassic fishes, Prof. Newberry himself graciously made easier the task of reducing the number of species by stating that intermediate forms might ultimately make reduction necessary. It is significant that in Dr. Woodward's Catalogue, only two of the American species are deemed worthy of description under the genus *Semionotus* (synonymous with *Ischypterus*), the remainder being merely listed as doubtful and probably

* Mon. U. S. Geol. Surv., No. xiv, 1888.
† Cat. Foss. Fish., British Mus. Nat. Hist., pt. iii.

based on inadequate material. It is to be regretted that Dr. Woodward had not an opportunity for a thorough revision of the American species of this genus. His decision to unite *Ischypterus* with *Semionotus* is satisfactorily borne out by the investigations of Dr. E. Schellwien, recorded in his valuable monograph.*

At the outset the question arises—what characters should be chosen for the basis of classification? Prof. Newberry placed much confidence in proportional length and depth. Dr. Woodward, relying on these proportions and also upon scale conditions, recognized, as stated above, only two American species of *Semionotus*. Although he has thus taught a wholesome and well-deserved lesson, he has probably been too severe in his judgment upon the work of American authors. Even granting that the cranial and facial bones originally possessed specific differences, it would be a profitless task to base the classification of the various species upon such characters, obscured as they now are throughout nearly the whole series of specimens. To the present writer the only safe course out of the difficulty seems to be to arrange this group of fishes mainly according to the character of the fins and scales, and when these are indistinct not to attempt the specific identification. Strict adherence to this method has resulted in the revision of species offered in this paper.

The search for specific characters has, however, led to something of greater interest. A specimen of *S. Marshi* from Sunderland, Mass., has been prepared in which the head bones are so clearly defined that an accurate drawing can be made of them (Plate VI, fig. 1). Although the bones of the maxillary arch and of the circumorbital series cannot be recognized, and the post-temporals are obscure, in other respects the preservation is remarkably good, and the forms of the bones which have been drawn may be considered fairly characteristic of the genus. The premaxillaries, which are lacking in this example, are shown distinctly in an otherwise poor specimen of *Semionotus* from Boonton, N. J. (Plate VI, fig. 4), whose specific identification is uncertain. In the figure of this latter specimen the left premaxillary is seen in advance of the right, and the paradoxical overlapping of the ascending process of the right premaxillary by that of the left probably resulted from maceration. In order to expose the entire premaxillaries it was necessary to remove part of the right frontal. Apparently, during life, the frontals overlay the upper third of the ascending processes of the premaxillaries.

With the drawing of the head bones it may be well to record

* "Über Semionotus Ag.," Königsberg in Pr., 1901.

here some characters of the scales which have not been emphasized by previous writers. The most handsome and complete specimens do not generally show the form of the overlapped portions of the scales. Such details are occasionally to be seen in the dissociated scales of fragmentary specimens. Unfortunately the same conditions which make this possible may also render the specific identification difficult and uncertain. Slightly at variance with Dr. Woodward's statement in regard to the scales,* "the narrow overlapped margin not produced at the angles," most of the American species show the antero-superior angle of the lower flank scales produced to a marked degree, and there is reason to suppose that this character holds good throughout the American division of the genus. Not only is the "peg-and-socket articulation" found in the flank scales generally, the pegs extending upward from the superior border of the scales, but the present writer has prepared for the Yale Museum an example of *Semionotus* from Boonton, N. J., in which the lower flank scales of the ventral region articulate by a second series of pegs and sockets (Plate VI, fig. 3). The antero-inferior angles of these scales bear peg-like processes, similar in size and form to those of the upper border, which lie under the posterior margins of the adjacent scales. The specimen displaying this double articulation is of uncertain specific identity, and it would be quite useless, at present, to speculate upon the prevalence of this character throughout the genus.

Semionotus fultus Agassiz.

Palæoniscus fultus L. Agassiz, 1833, Poiss. Foss., vol. ii, pt. i.
Palæoniscus fultus W. C. Redfield, 1841, This Journal. vol. xli.
Palæoniscus macropterus W. C. Redfield, 1841, ibid.
Ischypterus fultus Sir P. Egerton, 1847, Quart. Jour. Geol. Soc., vol. iii.
Ischypterus fultus J. S. Newberry, 1888, Mon. U. S. Geol. Surv., No. xiv.
Ischypterus macropterus J. S. Newberry, 1888, ibid.
Semionotus fultus A. S. Woodward, 1895, Cat. Foss. Fish., British Mus. Nat. Hist., pt. iii.

A number of specimens seeming to Prof. Newberry to offer slight differences in the proportions of length and depth were arranged by him in two species—*Ischypterus fultus* and *I. macropterus*. These specific names had been used previously, their history being as follows: In 1833 *Palæoniscus fultus* was given by Agassiz, in his *Poissons Fossiles*, to small and imperfect specimens from Sunderland, Mass. The species was afterwards placed in the new genus *Ischypterus*, by Sir Philip Egerton.† Meanwhile, the name *Palæoniscus fultus* was applied to specimens from Massachusetts, Connecticut, and

* Loc. cit. † Quart. Jour. Geol. Soc., vol. iii, 1847.

New Jersey, by W. C. Redfield,* who at the same time gave the name *P. macropterus* to specimens from these localities. It appears that there was some doubt as to the validity of the latter species, for, in 1848, a paper by J. H. Redfield was read before the Association of American Geologists and Naturalists, in which *I. fultus* and *I. macropterus* were discussed and were united under the name *I. fultus*. The late Prof. Newberry, belonging to a school of paleontologists whose practice it was to decide all doubtful cases in favor of new species, again separated the two forms; and finally Dr. Woodward (loc. cit.) reunited *I. macropterus* with *I. fultus*, and placed the latter in the genus *Semionotus*, where it will doubtless remain, for no generic difference has been shown between the American *Ischypterus* and the Old World *Semionotus* established by Agassiz in 1832.

The only character of *Semionotus macropterus*, as described by Prof. Newberry, that separates it from *S. fultus* is its relatively greater depth† of body. Even this the author did not state with much assurance, for after discussing the two species at length without contrasting them, he used the following words: "In most cases, however, there need be no doubt, the fusiform and slender fish standing for *I. fultus*, the broader one for *I. macropterus*." A careful examination of Prof. Newberry's original collection at Columbia University shows that, while one of the specimens (not a type) of *I. macropterus*, in its pressed and flattened condition, is deeper than a type of *I. fultus*, all the others are proportionately more slender. For this reason Dr. Woodward's decision will be adopted, and the specimens in the Yale Museum which have hitherto been labeled *I. fultus* and *I. macropterus* will now be exhibited under the name *Semionotus fultus*. The following description, while not as clear as could be desired, is as detailed as the condition of the fossils permits; and it will serve, at least, to distinguish good examples of *S. fultus* from well-preserved specimens of the other species:

S. fultus, attaining a length of 9 inches and a depth of 2½ inches. Origin of dorsal fin at mid-length.

Origin of anal fin under middle of dorsal fin or somewhat further to the rear, and on the third oblique scale-row in advance of the dorsal fin.

Origin of ventral fins slightly nearer to anal fin than to pectoral fins.

Dorsal fin fulcra about 12, rays about 10 (Plate V, fig. 1).

Anal fin fulcra about 12, rays about 10.

Dorsal and anal fin fulcra long. Apparently 4 dorsal fulcra

* This Journal, 1841.

† Termed "broader" by Newberry.

originate on the dorsal line over basal supports. The 5th dorsal fulcrum has its origin adjacent to that of the 1st ray, and is about equal in length to one-half the anterior margin of the fin.

Pectoral fins show, on the superior surface, about 10 fulcra, long and slender, and not widely divergent from the rays, which are about 10 in number (Plate V, fig. 2).

Ventral fins show, on the superior surface, about 10 fulcra.

Caudal fin has about 15 rays.

The best preserved specimens are a little less than four times as long as deep, the maximum depth being midway between head and dorsal fin, where the oblique scale-row comprises about 20 scales. Horizontal scale-row along lateral line comprises about 33 scales.

The deepest scales are in the 4th row behind the clavicular arch; these are twice as deep as long.* Scales of the anterior caudal region are nearly equilateral. With the exception of the scales of the lateral line, the anterior flank scales generally have the postero-inferior angles slightly rounded (Plate V, fig. 3), and the posterior flank scales have the postero-inferior angles produced into single points (Plate V, fig. 4). In rare and doubtful cases, the posterior borders of the flank scales may be slightly irregular, but never to the extent commonly seen in *S. micropterus.*

Semionotus micropterus Newberry.

Ischypterus micropterus J. S. Newberry, 1888, Mon. U. S. Geol. Surv., No. xiv.

One of the fishes placed by Dr. Woodward in his list of doubtful species is *S. micropterus.* It is encouraging to find that good specimens, not accessible when his Catalogue was compiled, now make it possible to describe this species more fully and to separate it from other forms by the characters of its fins and scales, and not solely by its contour. This species may be described as follows:

S. micropterus, attaining a length of 10 inches and a depth of 3 inches.

Relative position and size of fins about the same as in *S. fultus.*

Dorsal fin fulcra about 14, rays about 9 (Plate V, fig. 13).

Anal fin fulcra about 14, rays about 9.

Dorsal and anal fin fulcra relatively shorter than in *S. fultus.* Apparently 3 dorsal fulcra originate on the dorsal line over basal supports. The 5th dorsal fulcrum has its origin on the anterior margin of the 1st ray, at a point considerably removed

*These and similar measurements refer to the exposed portion of the scales, not to actual dimensions.

from the origin of that ray, and is about equal in length to one-third the anterior margin of the fin.

Pectoral fins show, on the superior surface, about 17 fulcra, which are shorter than in *S. fultus* and other species (Plate V, fig. 6).

The last scale of the anterior dorsal ridge has its posterior end slightly produced into a point (Plate V, fig. 11).

The best preserved specimens are a little more than three times as long as deep, and have a more strongly convex outline in the pectoral region than *S. fultus*.

In the majority of specimens, the flank scales, especially those below the lateral line, show a tendency to become bi- or tri-dentate on the postero-inferior angle (Plate V, figs. 7 and 8). Although this character is not always present, it may serve to identify the species in question, when the dorsal and pectoral fins are not preserved. No other species shows scales thus strongly dentate.

In reference to these dentate scales of *S. micropterus*, it is interesting to note that a specimen of this species, showing this character highly developed, but having the anterior dorsal ridge (characteristic of the genus) concealed, was labeled by Prof. Newberry "*Catopterus Redfieldi*." This error may have been caused by the presence of the "one or more posterior teeth" of the scales, given by Prof. Newberry as a character of *C. Redfieldi*, and also by the form of the pectoral fin fulcra, which offer a slight resemblance to those of *Catopterus*.

Semionotus Marshi W. C. Redfield.

Ischypterus Marshii W. C. Redfield, 1856, Proc. Am. Assoc. Adv. Sci. (Name only).

Ischypterus Marshii J. S. Newberry, 1888, Mon. U. S. Geol. Surv., No. xiv.

The Redfield Collection contains an imperfect fish about 12 inches long, from Sunderland, Mass., bearing the name *Ischypterus Marshii*. No description of this fish was published by the Redfields, although the name is found in a paper by W. C. Redfield entitled "On the Relations of the Fossil Fishes of the Sandstone of Connecticut, and other Atlantic States, to the Liassic and Jurassic Periods" (Proc. Am. Assoc. Adv. Sci., 1856). Prof. Newberry's monograph contains a plate and a description of this species, the credit for which is generously given to W. C. Redfield. Three other specimens from Sunderland, undoubtedly belonging to the same species as the above mentioned fish, are in the collection of the American Museum of Natural History in New York. According to the statement of Prof. Whitfield of that museum, their labels, bearing the name *I. Agassizii*, were written at the dictation of Prof. Newberry, when the latter was asked to identify them. This

incident is of especial interest in connection with the discussion of *I. Agassizii* in Prof. Newberry's monograph, where he writes "I have seen no such fishes as these anywhere except at Boonton. * * * At Sunderland occurs another species (*I. Marshii*) which in form and general aspect resembles those under consideration, but it is narrower, with less strong dorsal and anal fins, with thicker and relatively broader scales, which form more oblique rows on the sides. For these reasons I have thought it wise to regard it as distinct."

So far as comparison can be made, the three fishes at the American Museum of Natural History, labeled *I. Agassizii*, agree with the type of *S. Marshi* in size and form of body, size, form, and obliquity of scales, and relative position and structure of fins. The specific description here offered is based upon these specimens jointly with the type at Yale:

Semionotus Marshi, attaining a length of 12½ inches and a depth of 3½ inches.

Relative position and size of fins about the same as in *S. fultus*.

Dorsal fin fulcra about 14, rays about 9.

Anal fin fulcra about 14, rays about 9.

Apparently 4 dorsal fin fulcra originate on the dorsal line over basal supports, the 5th being nearly equal in length to one-half the anterior margin of the fin.

Pectoral fin fulcra about 14, rays about 12.

Ventral fin fulcra about 12.

The flank scales usually have the postero-inferior angles a little less pointed than in *S. fultus* (Plate V, figs. 5 and 12), and have the antero-superior angles continued forward as distinct processes under the overlapping scales (Plate V, fig. 9; Plate VI, fig. 2). The deepest scales are in the 3rd or 4th oblique row behind the clavicular arch; these are about twice as deep as long. Scales near the lateral line under the dorsal fin are equilateral.

The maximum depth is midway between the pectoral and ventral fins, where the oblique rows comprise about 19 scales. Horizontal row along lateral line comprises about 34 scales.

The last scale of the anterior dorsal ridge has its posterior end produced into a fine point (Plate V, fig. 10).

Semionotus tenuiceps Agassiz.

Eurynotus tenuiceps L. Agassiz, 1835, Poiss. Foss., vol. ii, pt. i.
Eurynotus tenuiceps J. H. Redfield, 1837, Ann. Lyc. Nat. Hist. N. Y., vol. iv.
Palæoniscus latus J. H. Redfield, 1837, ibid.
Ischypterus tenuiceps J. S. Newberry, 1888, Mon. U. S Geol. Surv., No. xiv.
Semionotus tenuiceps A. S. Woodward, 1895, Cat. Foss. Fish., British Mus. Nat. Hist., pt. iii.

This is one of the two American species of *Semionotus* approved by Dr. Woodward. Except in its young form it may be

easily distinguished from other species by the peculiar development of the scales of the anterior dorsal ridge. Dr. Woodward describes his type in the collection of the Geological Society of London as follows:

"A species attaining a length of about 0·2 [m]. Trunk with a considerably arched dorsal border, the depth of the caudal pedicle more than one-third as great as the maximum depth of the abdominal region. Length of head with opercular apparatus less than the maximum depth of the trunk, and contained four times in the total length of the fish. Fins as in *S. fultus*. Scales smooth and not serrated, those of the middle of the flank in part twice as deep as broad; dorsal ridge-scales large and conspicuous, comparatively obtuse in large specimens."

To this may be added that the last scale of the anterior dorsal ridge has its posterior end blunt and not produced, while the scale on the ventral line immediately in front of the anal fin has its posterior end notched. The ribs are more strongly developed than in other species.

Semionotus ovatus W. C. Redfield.

Palæoniscus ovatus W. C. Redfield, 1841, This Journal, vol, xli.
Ischypterus ovatus Sir P. Egerton, 1850, Quart. Jour. Geol. Soc., vol. vi.
Ischypterus ovatus J. S. Newberry, 1888, Mon. U. S. Geol. Surv., No. xiv.

Several specimens are to be found bearing this name, but, as far as the writer can ascertain, only one, the type at Columbia University, is so well preserved as to afford specific distinction. The only character given hitherto in which this species differs from others is the greater proportionate depth of body midway between the head and dorsal fin. The type specimen, however, shows another character which will probably be found more reliable, viz., a greater number of dorsal and anal fin fulcra than is found in the other American species of this genus.

S. ovatus, length 11 inches, depth 3¾ inches.

Position and size of fins about the same as in *S. fultus*.

Dorsal fin fulcra 21, actually preserved.

Anal fin fulcra 19, actually preserved.

Apparently 5 dorsal fin fulcra originate on the dorsal line, and the 6th is equal in length to a little less than one-half the anterior margin of the fin (Plate VI, fig. 5).

There is much confusion about the localities ascribed to the American species of *Semionotus*. For example, the two imperfect specimens to which Agassiz applied the name *S. fultus* were found at Sunderland, Massachusetts, and specimens in the Redfield Collection, whose original labels were *S. fultus*, have proved to be *S. tenuiceps* from Massachusetts and *S.*

micropterus from Connecticut. It is certain, however, that Prof. Newberry's types of *S. fultus* and *S. macropterus*, illustrated in his monograph, are from Boonton, New Jersey, and that all the specimens in the Redfield Collection which agree with these types are from New Jersey also; indeed it is possible that *S. fultus* of Newberry should be rightly considered as limited to that state.

S. micropterus is known only from Connecticut.

S. Marshi probably occurs in Massachusetts, Connecticut, and New Jersey.

S. tenuiceps is a Massachusetts species which is doubtfully from Connecticut.

S. ovatus (type) is from Boonton, New Jersey.

The other species of *Semionotus* described by Prof. Newberry in his monograph must remain of doubtful validity until their claims for distinction are better supported. Indeed the difficulty of the situation cannot be better shown than by quoting Dr. Woodward's sweeping statement: "Nearly complete fishes, variously crushed and distorted and sometimes imperfectly preserved, have been described from the Trias of North America under the following names. They may be conveniently referred to the genus *Semionotus*, and doubtless represent much fewer species than are here enumerated." Then follows a list of all the American species except *S. fultus* and *S. tenuiceps*. It is the present writer's hope that these notes may serve to reëstablish three of the species thus lately discredited, and may place the classification of this genus on a firmer basis.

Catopterus J. H. Redfield.

This genus is represented in the Yale Collection by J. H. Redfield's type of *C. gracilis* and by a remarkably good series of specimens from the Trias of New Jersey and of the old Connecticut River valley, which probably belong under the type species, as they agree in the main with the characters of that species given by Dr. Woodward. The only addition to the knowledge of the structure of this genus is the determination that the flank scales were interlocked by a single peg-and-socket articulation. From the superior margins of these scales arise pegs similar to those which characterize the superior margins of the flank scales of *Semionotus;* but no articulating processes have been found projecting from the antero-inferior angles. As flank scales can be seen in the closely allied genus *Dictyopyge*, which articulate in a like manner, it is evident that the single peg-and-socket articulation is characteristic of the Catopteridæ.

Yale University, February 24, 1903.

EXPLANATION OF PLATES.

Plate V.

Figure 1.—*Semionotus fultus;* dorsal fin.
Figure 2.—*S. fultus;* pectoral fin.
Figure 3.—*S. fultus;* anterior flank scales.
Figure 4.—*S. fultus;* posterior flank scales.
Figure 5.—*S. Marshi;* scales from 12th oblique row, a little below lateral line.
Figure 6.—*S. micropterus;* pectoral fin.
Figure 7.—*S. micropterus;* anterior flank scales.
Figure 8.—*S. micropterus;* posterior flank scales.
Figure 9.—*S. Marshi;* posterior flank scales.
Figure 10.—*S. Marshi;* last scale of anterior dorsal ridge.
Figure 11.—*S. micropterus;* last scale of anterior dorsal ridge.
Figure 12.—*S. Marshi;* scales of 7th and 8th oblique rows, immediately below lateral line.
Figure 13.—*S. micropterus;* dorsal fin.

All the figures are twice natural size.

Plate VI.

Figure 1.—*S. Marshi;* head; natural size.
Fr., frontal; *Pa.*, parietal; *S.t.*, supratemporal; *Sq.*, squamosal; *P.or.*, postorbital; *Op.*, operculum; *P.op.*, preoperculum; *I.op.*, interoperculum; *S.op.*, suboperculum.
Figure 2.—*S. Marshi;* lower flank scale, showing articular process; natural size.
Figure 3.—*Semionotus*, sp.; lower flank scales, showing double articulation; four times natural size.
Figure 4.—*Semionotus*, sp.; premaxillæ; natural size.
Figure 5.—*S. ovatus*; dorsal fin; twice natural size.

Art. XXIX.—*The Mechanics of Igneous Intrusion;* by Reginald A. Daly.

CONTENTS.

Introduction 269
The "laccolithic theory" of plutonic intrusion 269
The "marginal assimilation" theory of plutonic intrusion 270
The Hypothesis of Overhead Stoping by Deep-seated Magmas 272
The relative densities of holocrystalline, glassy, and molten rock at ordinary atmospheric pressure 273
Influence of plutonic pressures on rock density 278
Relative densities of solid and molten rocks under plutonic conditions 279
Fluidity of plutonic magmas 281
Enclosures of foreign rocks in the endomorphic zones of intrusives 280
Overhead stoping in magmas of high fluidity 282
The opening of the magma chamber 282
Tests of the Hypothesis of Overhead Stoping 285
Testimony of laccoliths 285
Abyssal assimilation 287
Formation of compound magmas by abyssal assimilation 290
Differentiation of compound magmas 290
The eruptive sequence 292
Summary 295
General Summary on the Mechanics of Igneous Intrusion 297

The problem of the origin of the igneous rocks is intimately associated with the need for clear definition of all the possible methods according to which chambers now occupied by intrusive bodies may have been prepared to receive their respective magmas. Then the recognition of the relative importance of these methods, in explaining the vast number of such chambers now exposed to the light, becomes a second step in the direction of solving the genetic problem. However, those rock bodies—dikes, sheets or sills and true laccoliths—about the intrusion mechanics of which there is a fair consensus of opinion among geologists, are certainly the least notable as to volume among the intrusive masses of the earth. The enormously more important stocks and allied greater granitic bodies to this day form the subject of controversy which, though well regulated by fact, is as vigorous as in the days of Hutton and Werner.

The "laccolithic" theory of plutonic intrusion.—One school of geologists would extend the laccolithic idea to many, if not most, granitic intrusions. Accordingly, the chambers filled with such igneous masses are interpreted as the products of crustal displacement. The planes of single great faults may, in this way, become the locus of the subterranean eruption of magmas, wedging their way along by hydrostatic or other pressure. The well-known "failure to match" of the heaved and thrown sides permits of the existence of potential cavities filled

with magma during the strong dislocation. Encircling faults leading to the foundering of large blocks of the crust, or to the upward thrust of others, are conceived as affording possible modes of intrusion.* Or, finally, as illustrated in the well-known conclusions of Brögger on the Christiania region, colossal masses of granite have been explained as true, deep-seated laccoliths, parting heavy strata after the manner of the trachyte of the Henry Mountains.† Yet it is clear from a survey of geological literature, that the field evidence for such a view is but negative in the great majority of stocks and so-called "batholiths." Most of them are not true laccoliths, as they characteristically occur in regions of great structural complexity, where igneous contacts have none but the most remote sympathy with the structural planes of any one bedded series. Many are much too large and irregular in form to be explained as the result of single faults or single zones of faulting; and the imagined intersecting faults of the "bysmalith" or of the submerged graben-block have been generally sought for in vain about those greatest of all granitic massifs. For the latter no other interpretation seems possible by the theory outlined. On the other hand, every observer who has even a small acquaintance with crystalline terranes of the sort, is now and again struck with the evidences that the granitic magmas represented in his field of study were far from being passive in the hands of the eruptive Titan. Their general defiance of structure and composition in the invaded formations, the irregular ground-plans, and the huge finger-like projections sent into the country-rocks,‡ which are undisturbed either in dip or strike, are among the familiar phenomena indicating that such magmas actively, aggressively, "made their way in the world" by the irregular removal of the invaded formations. The latter look as if they had been, as it were, corroded on a huge scale.

The "marginal assimilation" theory of plutonic intrusion.—Emphasis has, therefore, been laid by a second school of geologists on a hypothesis of slow caustic action by magmas that have advanced into the overlying earth-crust by their own energetic solvent action on their walls and roofs. Additional evidence for the truth of this contention is sought in the facts of the internal contacts, at which magmas are sometimes seen to be modified by the incorporation of the country-rock. This

* W. C. Brögger, Die Eruptivgest. des Kristianiagebietes, vol. ii, 1895, p. 148; J. P. Iddings, U. S. Geol. Surv., Monograph xxxii, Part 2, 1899, p. 16.

† Op. cit., p. 152.

‡ The author will use this term throughout the paper as a synonym for "invaded formation," meaning the rocks cut by, and in contact with, an intrusive. Mining terminology also gives "roof" and "wall" for the upper and lateral surfaces of contact between intrusive body and invaded formation. This temporary appropriation from a kindred science will prove of convenience in the following discussion.

second view doubtless appeals the more strongly to the majority of those geologists who have actually to do with granitic bodies in the field. In fact, the impression has prevailed among some of them that the "laccolithic theory" is as widely held as it is because of its apparent necessity in the prevailing theory of rock-differentiation. Yet it must be considered as conclusively proved for the great majority of stocks and batholiths investigated, that analysis has not yet shown that the second or "assimilation" theory really meets its own crucial test, the chemical and mineralogical blood-relationship between the average intrusive rock and its country-rock along their mutual contact. Currents within the magma would, of course, tend to remove and diffuse products of assimilation from molar contacts;* but it is extremely doubtful that they could so completely mask the expected results of the process as is over and over again illustrated in nature. No single fact concerning granite, for example, is more striking than its astonishing homogeneity in contact with argillite, limestone, crystalline schist or basic igneous formation—a homogeneity that persists, too, from contact to center of the eruptive. In the very common case where the assimilated product is more acid than the original magma, it would tend to rise through the latter, slowly diffusing in the journey. The upper part of the magma basin should, for that reason, become filled with a mixed magma more siliceous than the original. Heterogeneity, even stronger vertically than horizontally, would be expected in a diorite or gabbro magma cutting crystalline schists, or in a granite magma cutting heavy beds of sandstone or quartzite. True thermal convection currents must, under these conditions, be greatly weakened by the strong differences in density of the original magma and the magma diluted, so to speak, by more siliceous material. In the absence, then, of the only kind of current likely to be set up in the process of cooling and mere caustic solution on molar contacts, the diffusion of the diluted magma would take place only with extreme slowness.† Yet, up to the present time, this consequence of considerable vertical heterogeneity under the stated conditions has not been demonstrated in nature. The recorded field discoveries point, on the contrary, to a distinct failure of the known facts to match the deduction from the theory. The few proved instances of endomorphic changes of magmas by assimilation (e. g., the granite of the Pyrenees described by Lacroix) serve, by their conspicuous

*For ease of reference to the great surfaces of contact between intrusive bodies and the terranes cut by them, as distinguished from the contacts of the corresponding igneous rocks and foreign fragments caught in them, the author again introduces a term not in general use but convenient for temporary employment. The former are called "molar contacts."

†Cf. Becker, this Journal (4), iii, p. 30, 1897.

and exceptional nature, to show that granitic magmas, if they have "made their own way" at all, have usually done so in some manner different from merely assimilating the invaded formations on molar contacts.

In a limited fashion, both theories may be accepted as giving the required explanation of actual occurrences of igneous rocks. But what is to be the final conclusion regarding the much greater family of granitic bodies where the objections to both the laccolithic and assimilation theories are felt in full force? They form a riddle for which the writer has been able to find no solution in the existing literature of intrusion. As a contribution to that old and difficult theme, he offers, in the following pages, a brief outline of certain suggestions which have come to him as a result of field study in New England and Canadian areas of granitic formations.* For the sake of brevity, the hypothesis to be proposed will assume a more general character than that warranted by the discussion of any one area, wherein local facts would have to be related with unnecessary detail.

The Hypothesis of Overhead Stoping† by Deep-seated Magmas.

Believing that assimilation by magmatic action of some kind is responsible for practically all the chambers occupied by those intrusives with which he is more or less intimately acquainted, the writer has sought for field evidence as to whether any other sort of assimilation is possible than that by caustic or solvent action of a magma on its roof and walls. Such information is found in the same internal contact-belt where the general failure to prove solutional absorption of the country rock has been so often reported. Within that belt it is the rule to find often very numerous blocks of the invaded rocks. Tnese have usually the following characteristics: varying size; angular or subangular outlines against the eruptive rock, which is essentially unmodified even close to the contact with each block; sharp contacts with the eruptive, in which the blocks are completely immersed; a normally high crystallinity and increased density as a result of contact metamorphism. Very often they show that they have moved but short distances from the niches they once occupied in wall or roof. The molar contact is similarly sharp. It may preserve, with exceeding definiteness, the sharp corners left when the blocks were rifted off. Passing, now, inwards, it is an equally normal thing to find

* A few paragraphs in the paper are identical with passages in a forthcoming bulletin (No. 209) of the United States Geological Survey on the "Geology of Ascutney Mountain, Vermont."

† A technical mining term meaning to excavate upwards or sideways to remove ore.

the foreign inclusions to become rapidly rarer, until, in the heart of the eruptive area, one may go hundreds of yards or even several miles without discovering any such inclusions. If there are hundreds of them in a given part of the contact-belt at the present surface (evidently a chance section exposed by erosion), the natural inference that there are thousands or millions of others enclosed in the eruptive below the level of the visible contact, is clearly permissible. Another legion of them has been destroyed along with their matrix in that part of the igneous body removed by denudation. It is manifest, further, that the rifting of the blocks has *so far* enlarged the chamber occupied by the eruptive. That is, the walls are, on the average, farther apart because of the rifting. The question arises as to whether the chamber may owe the greater part of its present size to a long continuation of the selfsame process, with a simultaneous removal from the visible chamber of the blocks formerly rifted off. The affirmative answer to this question is the kernel of the hypothesis to be proposed.

Strangely enough, the explanation of the presence of foreign blocks within igneous bodies along the molar contacts and the equally conspicuous rarity of such fragments toward the centers of the bodies, has not been, so far as the writer is aware, adequately discussed anywhere in geological literature. How blocks still close to their former homes in the country rock could be suspended in the magma until crystallization of the latter was complete, and whether the normal effect of their complete immersion would be to permit of their floating upwards or sinking downwards in the magma, are questions not as yet properly answered. It will be seen that these queries are of prime importance to the ensuing hypothesis and that the attempt has been made to answer them by correlating experimental and other data acquired for petrological science within recent years. We may, for the present, assume the generally accepted high liquidity of normal plutonic magmas, though in the sequel certain arguments therefor will be given in brief outline.

The relative densities of holocrystalline, glassy, and molten rock at ordinary atmospheric pressure.—As the foundation of the argument, the very careful and fruitful experiment in the dry fusion of diabase by Barus must be briefly described.*

With a much greater refinement and accuracy of method than that practised by any of his predecessors, Barus has measured the density of a sample of normal diabase at normal pressure (one atmosphere) and temperature (20° C.), and compared therewith the densities of the completely melted rock and of

* Phil. Mag. (5), xxxv, 173 (1893), and U. S. Geol. Surv. Bull. No. 103 (1893). Cf. Joly, on the fusion of basalt, Trans. Roy. Dublin Soc. (2), vi, 298 (1897).

the glass resulting from the rapid cooling of the fused product, both glass and molten rock being again under one atmosphere of pressure. His results are summarized in the following table and list of conclusions from his own more detailed scheme of observations and from his important fusion curve. As it is expedient in the present connection to choose a reference temperature that will be high enough to allow of a degree of superheating of any plutonic rock-type sufficient to keep it molten even under several thousand atmospheres of pressure, the writer has chosen 1400° C. as the basis for comparison of the densities of molten magmas.

TABLE I.

	Temperature.	Volume ratios.	Specific gravities.
Rock	20° C.	100	3·0178
Glass	20°	111·2	2·717
Molten rock	1400°	119·6	2·523

Increase in volume in passing from glass at 20° C. to molten condition at 1400° C. ..... 7·7 %

Increase in volume in passing from glass at 20° C. to melting point at about 1090° C. ..... 2·8 %

Net decrease in specific gravity in passing from rock at 20° C. to glass at 20° C. ..... 10 %

Decrease in specific gravity in passing from glass at 20° C. to molten condition at 1400° C. ..... 7·1 %

Decrease in specific gravity in passing from rock at 20° C. to molten condition at 1400° C. ..... 16·4 %

Decrease in volume in the act of solidifying to a glass. 3·9 %

There was a notable and sudden increase in volume at melting. The expansion was steady up to the melting point and again steady, but more rapid after melting than before, being about 1·9 times faster.

Barus also gives a timely explanation of the reason why a fragment of solid diabase will not readily be made to sink in the molten glass of its own substance. He shows that a "boat," made of chilled glass, is instantly formed about the cold fragment as it meets the surface of the fused mass. A full corroboration of his conclusion that such a fragment, once completely submerged in the non-chilled molten glass, must forthwith sink, has been given by Lagorio's experiments.* They also correspond with observations by Johnston-Lavis, who has seen compact lava sink in a liquid flow from Vesuvius.†

A critical comparison of other experimental studies with those of Barus indicates that they fully bear out his conclu-

* Tscher. Min. u. Petrog. Mitth., viii, 510 (1887).

† Quart. Jour. Geol. Soc., xxxviii, Proc., 240 (1882). Cf. Dutton at Kilauea, 4th Ann. Rep. U. S. Geol. Surv., 106 (1884).

sions. Mallet and others have shown reasons for scepticism as to the accuracy of Bischof's early work in fusion, while Gilbert pointed out the patent error of Mallet's own method of criticism.* Forbes found a net expansion of 6·4 per cent in the passage of basalt at 20° C. to glass at the same temperature, but, however accurate, his result is not here of great value as he has given no information as to the degree of vesicularity or crystallinity of the original rock.† These two characters are so important that the further analysis of experiments older than those of Barus, had best be concerned only with those in which only holocrystalline, plutonic rocks or allied crystalline schists were employed in fusion. The most reliable of these known to the writer were made by Delesse‡ and by Cossa.§ Delesse made in all forty-seven fusions, but many of them must, for our present purpose, be discarded because of the vesicularity of the fused products. He measured the densities of the various rocks at normal atmospheric pressure and temperature, and those of their respective glasses under similar conditions. The most reliable of these determinations are entered with those of Cossa in Table II.

TABLE II.

Authority.	Rock type.	Spec. grav. of rock.	Spec. grav. of glass.	Net decrease in density.
Delesse	*Granite*	2·730	2·450	10·26 %
		2·623	2·360	10·03
		2·684	2·423	9·72
		2·680	2·427	9·44
		2·751	2·496	9·27
		2·700	2·447	9·37
		2·660	2·425	8·84
		2·643	2·478	6·24
Cossa	*Syenite*	2·710	2·430	10·33
Cossa	*Quartz diorite*	2·667	2·403	9·90
Delesse	*Diorite*	2·921	2·679	8·29
		2·799	2·608	6·82
		2·858	2·684	6·09
Delesse	*Gabbros*	3·100	2·664	14·06
		2·898	2·641	8·87
Delesse	*Gneiss*	2·821	2·625	6·95

If, now, we bring the averages of the last table into comparison with the results of Barus on diabase, we have Table III:

* Rep. on the Geol. of the Henry Mts., p. 76, Washington (1887).
† Chemical News, Oct. 23, 1868.
‡ Bull. Soc. Géol. France (2), iv, 1380 (1847).
§ Zirkel, Lehrb. d. Petrographie, i, 681 (1893).

TABLE III.

Rock type.	1. Sp. gr. of rock at ca 20° C.	2. Sp. gr. of glass at ca 20° C.	3. Net decrease in density, rock to glass.	4. Net increase in vol., rock to glass.	5. Sp. gr. of rock molten at 1400° C., cal. from Barus's fusion curve.
Diabase of Barus	3·0178	2·717	10·00 %	11·2 %	2·523
Av. gabbro of Delesse	2·999	2·642	11·57	13·1	2·507
Av. diorite "	2·859	2·657	7·07	7·6	2·390
Q. diorite of Cossa	2·667	2·403	9·90	11·1	2·229
Syenite of Cossa	2·710	2·430	10·33	11·5	2·266
Av. granite of Delesse	2·684	2·438	9·16	10·0	2·243
Av. of all above			9·67	10·7	
Gneiss of Delesse	2·821	2·625	6·95	7·5	2·358

The conclusions immediately derivable from columns 3 and 4 are: first, that the results of Barus, Delesse and Cossa on the whole agree closely and are mutually corroborative; secondly, that the net expansion increment of diabase in passing from the holocrystalline to the glassy state (at one atm. pressure), is nearly the average for all plutonic types; thirdly, that the agreement of Barus and Delesse is specially close when the two observers used rocks of nearly equivalent chemical composition; fourthly, that, from the similar behavior of plutonic types within the limits investigated, it is fair to consider it highly probable that all the types would be characterized by nearly the same rate of expansion in passing from the holocrystalline to the molten state at 1400° C., although experimental data be now lacking for testing the justice of that inference. (Col. 5 contains the values of the corresponding specific gravities calculated from Barus's fusion curve as the standard); and, lastly, that, as expected, decreasing acidity means increasing density of the molten magma at 1400° C.

In view of the disturbing influence of vesicularity and of variable crystallinity in his lavas, it appears that Delesse's table showing that thermal expansibility is strongly affected by basicity (fusibility), is unreliable.* In fact, so closely accordant are the various rock-types referred to in Tables II and III, that we may not expect serious error in applying Barus's accurate expansion curve to plutonics generally. The writer has therefore constructed Table IV, in which col. 1 represents the range of specific gravity found in the different chemically analyzed types noted in Rosenbusch's Elemente der Gesteinslehre. Col. 2 represents the range of specific gravity (calculated from the fusion curve) in the same rocks molten at 1400° C. and at normal atmospheric pressure. Col. 3 gives the specific gravities of the same rocks supposed to follow the law of normal

*Op. cit., p. 1390.

expansion (according to the curve) as solid bodies, but at 1400° C. Col. 4 gives the specific gravities under the conditions of col. 3, but calculated from the expansion coefficients of Reade.* It follows from this calculation that, if average sandstone, marble, slate, and granite should expand uniformly as solid bodies to 1400° C. and according to the rates set forth in those coefficients, the rocks would expand respectively 4·2, 4·1, 3·9 and 3·7 per cent in volume. The increase for diabase under similar conditions but calculated from the ratio of expansion in solid diabase as determined by Barus, is 3·6 per cent. These figures and a comparison of cols. 3 and 4 indicate a remarkable agreement in the results of quite independent experiments using different methods. It will be noted that col. 2 is carried out only for the plutonic massive rocks with which we are here chiefly interested. Further, the legitimacy of extending that column to cover the sediments and schists may be questioned, although the isolated experiment of Delesse on gneiss (Table III) seems to show a thermal expansion behavior for gneiss comparable to that of the standard diabase. In the preparation of col. 4, Reade's coefficient of marble was used for the limestone and dolomite, his coefficient of slate for shale and phyllite, and his coefficient of granite used for the other crystalline schists and for the more acid igneous types. In cols. 2 and 3, a minimum of error adheres to the figures for types *a* to *d*, inclusive, which are most nearly allied in composition to diabase.

TABLE IV.

Rock-type.	1. Range of sp. gr. at 20° C.	2. Range of sp. gr. at 1400° C. (molten).	3. Range of sp. gr. at 1400° C., (solid) from fusion curve.	4. Range of sp. gr. at 1400° C., (solid) from Reade's coefficient.
a. Peridotites	2·90–3·35	2·42–2·80	2·80–3·23	
b. Gabbros	2·80–3·20	2·34–2·68	2·70–3·09	
c. Average gabbro	3·10	2·59	2·99	
d. Diorites	2·70–3·00	2·26–2·51	2·61–2·90	
e. Elaeolite syenites	2·45–2·60	2·06–2·17	2·36–2·51	2·36–2·51
f. Common syenites	2·60–2·86	2·17–2·39	2·51–2·76	2·51–2·76
g. Granites	2·60–2·73	2·17–2·28	2·51–2·63	2·51–2·63
h. Sandstone and quartzite	2·15–2·75		2·07–2·65	2·06–2·64
i. Pure limestone	2·72		2·63	2·62
j. Pure dolomite	2·87		2·77	2·76
k. Shales and clay slates	2·40–2·80		2·31–2·70	2·30–2·69
l. Average phyllite	2·75		2·65	2·64
m. Gneisses	2·60–3·00		2·50–2·90	2·50–2·90
n. Mica schists	2·75–3·10		2·65–2·99	2·65–2·99
o. Amphibolites, etc.,	2·80–3·30		2·70–3·19	2·70–3·19

* Origin of Mountain Ranges, p. 110, 1886.

Influence of plutonic pressures on rock density.—Before drawing any conclusions concerning the possibility of the flotation of foreign blocks of solid rock in a plutonic magma, it is clear that a preliminary and difficult stage of our inquiry must be passed. What influence has pressure at great depths on the *relative* densities of solid blocks and of the liquid magma in which they are immersed? One can hardly doubt that water and mineralizers in depth would increase such differences as those calculated for one atmosphere of pressure and 1400° C.; so that Gilbert's conclusion as to the difficulty of determining the densities of hydrothermally molten magmas need not affect the present argument except in a favorable way.* Since the temperatures of a block and its enclosing magma are practically identical, the final step in deciding on their relative densities in depth is taken, if it can be shown what is the relative compression suffered by the solid and liquid.

Again we must have recourse to the valuable experiments of Barus as those, of any known to the writer, most nearly related to the problem at issue. He concludes, as a net result of his investigations, that "the relation of the melting-point to pressure in case of the normal type of fusion is nearly constant irrespective of the substance operated on. . . . And in the measure in which this is nearly true on passing from the carbon compounds to the thoroughly different silicon compounds, is it more probably true for the same substance changed only as to temperature and pressure. In other words, the relation of melting-point to pressure is presumably linear."† Accepting his inferences as sound, the fact remains that his experiments on thymol, naphthalene and other carbon compounds can throw light on the behavior of silicate magmas in other respects than that cited in the foregoing quotation. This important deduction is corroborated by the proved similarity of silicates and carbon compounds, in (*a*) the linear relation of expansion to increment of temperature in the solid form of each substance, in (*b*) the linear relation of expansion to increment of temperature in the liquid form of each substance, and in (*c*) the sudden leap in volumetric increment in the act of melting at any temperature.‡

Barus further indicates that solid naphthalene is comparable in compressibility with the liquid form of the same substance.§

* Rep. on the Geol. of the Henry Mts., p. 76 (1877).

† Phil. Mag., xxxv, 306 (1893), and U. S. Geol. Surv., Bull. 103, p. 55 (1893); cf. this Journal, xxxviii, 407, 1889, and xlvi, 141 (1893).

‡ Barus and others have shown that even the exceptional type of fusion represented by ice, becomes the normal type as a not high temperature is reached under a condition of great pressure. This Journal, xli, 326 (1891).

§ This Journal, xlii, 140 (1891).

His fusion curves show that, for the same increase of pressure, liquid naphthalene gains in specific gravity about twice as fast as solid naphthalene. The compressibility of a fused silicate rock is probably, then, about twice that of the same rock when solid. But his diabase fusion curve demonstrates that the thermal expansibility of the liquid rock is about 1·9 times as great as that of the solid rock. Thus a block of cold, solid gabbro immersed in a deep-seated molten magma of the same chemical composition, would be less condensed by the pressure than the molten rock, but the effect on relative densities would be partly compensated by any superheating of the magma. It is, moreover, clear from the facts of cols. 1, 3 and 4, Table IV, that, at 1400° C., this different thermal expansibility would occasion but a small difference in the respective ratios of the specific gravities of a solid rock at ordinary temperature and at 1400° C. to the specific gravity of a magma at the latter temperature. The same is doubtless true of compressibility, since that property bears a simple relation to expansibility. The compressibility of glass and of crystalline silicates is known to be very low. The compression suffered by glass, for example, is about ·0000026 of its volume for 1 atm. The weight of even 10,000 meters of rock with an average density of 2·75 would cause a density increase of much less than one per cent in glass. It is therefore probable that the difference of density between magma and immersed block would not be affected through pressure, at the great depth of 10 kilometers, by as much as 1 per cent of the density of either one.

Relative densities of solid and molten rocks under plutonic conditions.—It is perhaps necessary to state that any errors introduced by the application of the expansion coefficients of Barus and Reade to rocks differing from their types, cannot seriously vitiate cols. 3 and 4 in the table; and that the *relative* differences of density signalized in cols. 2 and 3, or 2 and 4, Table IV, will persist practically unchanged, whether the solid rock is immersed at a temperature near its melting point or a couple of hundred degrees above it.

Not with absolute certainty, then, but with high and cumulative probability, we are entitled to use cols. 2 and 3, or 2 and 4, of Table IV as expressing the essential contrast of densities between plutonic magmas and fragments of solid rock rifted off by them from the walls or roof of their respective chambers. The following conclusions are thus possible:

1. A solid block of each igneous rock would sink in its own molten glass.

2. Blocks of the basic eruptive rocks would sink in all of the magmas except in a very basic peridotite.

3. Blocks of the heavier granites and syenites would sink in all magmas except the more basic gabbros and peridotites.

4. Blocks of all the average sediments and schists would sink in any molten magma except the denser gabbros and peridotites.

5. Blocks of many of the sandstones would float in syenitic (trachytic) magma, and argillites would float in the denser kinds of the same magma.

6. The lighter gneisses, argillites, quartz rocks, and probably many limestones, would float in the average gabbro magma, in which, however, the other sediments and schists would sink. This means that the great majority of the solid crystalline schists would be denser than average molten gabbro under plutonic conditions, although the former are about equal in density to molten basic gabbro.

It must be considered, too, that even the densest gabbro or peridotite would tend to become somewhat acidified, and thus lose in specific gravity, when in contact with those same siliceous rocks which alone would float in that magma. Consequently, any immersed blocks would tend to sink to a greater or less depth depending on the extent of the acidification. Secondly, the normal increase of density due to the contact metamorphism of siliceous and calcareous sediments and many crystalline schists invaded by hypogeal magma, must add to the likelihood that detached blocks from the country rocks could not remain in suspension in the magma. How significant can be the density increment due to exomorphic changes is illustrated in Rosenbusch's classic researches in the Steiger Schiefer, in Gilbert's account of the contact action about the Henry Mountains laccoliths, and in a great number of other studies to which further reference is unnecessary.

Fluidity of plutonic magmas.—Brögger has summarized most of the arguments for the general high liquidity of granitic and other deep-seated magmas.* They are so convincing that this question, postponed from an earlier stage in the present line of thought, need not detain us long. The known attributes of those portions of such magmas as reach the surface of the earth as lavas, and the common abundance of thin but often remarkably long, apophysal sheets and dikes from the main intrusive bodies, are facts too well established to permit of essential doubt as to high fluidity. Nothing can seem more probable than that the relatively small fall in temperature, represented in the passage of a thinly molten magma to a toughly viscous condition, has actually taken place in plutonic bodies. Doelter has shown experimentally that that decline in temperature under surface conditions may be from 1240° C.

* Die Eruptivgest. des Kristianiagebietes, iii, 336 (1898).

to 1150° C. for granite, from 1070° to 1010° C. for phonolite, and from 1060° to 992° C. for basalt.* It is clear from Barus's researches that similar differences would be expected under plutonic conditions of pressure. Without dwelling on the older experiments proving that the presence of water and "mineralizers" aids in giving a magma mobility, the more recent one by Barus may be noted.† He has been able to fuse glass at 200° C. in the presence of water! Finally, Oetling found that, when a magma is once molten, the pressure of 200 or 300 atms. tends to keep it molten longer than under normal pressure.‡ Amagat, before him, came to the view that, provided the pressure be high enough, solidification may be indefinitely held back.§ However this may be, experiment fully substantiates the conclusion enforced by field evidences, that plutonic magmas are highly fluid during active intrusion.‖

Enclosures of foreign rocks in the endomorphic zones of intrusives.—To return to the original problem of the country rock inclusions actually seen in the field at internal intrusive contacts. We have found grounds for believing that such blocks could not, in the vast majority of occurrences, have remained in their present positions close beside the niches in the wall or roof whence they came, unless the magma enclosing them were very viscous at the time they were rifted off. Additional testimony to this mechanical indication of high viscosity is derivable from the normal chemical inactivity of the magma in contact belts of the kind. The blocks, as a rule, show few absorption phenomena or none at all, and are but rarely accompanied by diffusion aureoles. The boundaries of the fragments against the igneous rock are more often than not exceedingly sharp, like the new molar-contact surface formed by the rifting away of the same blocks. Lastly, the contact-metamorphic changes wrought in the blocks are often no greater than those effected in the country rock many yards from the molar contact. Viscosity of about the same degree will explain the suspension of the basic segregations in granites, syenites, etc., and probably approaches that of the Archæan granitic magmas which, according to Lawson, were capable, under enormous dynamic stresses, of shearing and attenuating foreign blocks suspended in those magmas near the moment of consolidation of the latter. Lawson has also suggested that, although the viscosity was so great, the temperatures may have been high enough to melt up the more basic fragments com-

* Tscher. Min. u. Petrog. Mitth., xx, 232 (1901).
† This Journal, vi, 270 (1898).
‡ Tscher. Min. u. Petrog. Mitth., xvii, 332 (1897).
§ Comptes Rendus, No. 16 (1893).
‖ Cf. Iddings, Jour. Geol., i. 893 (1893); A. Geikie, Ancient Volcanoes of Great Britain. ii, pp. 413–22–39 (1897).

pletely.* Whether solid or molten when sheared or pulled out, such blocks could not sink in the magmas because of their thick-pasty condition.

Overhead stoping in magmas of high fluidity.—If then, a visible contact zone shows that its magma could, in the enfeebled condition just prior to solidification, rift off blocks in great number from the invaded formation, it is clear that the same magma could carry on the destructive work much more rapidly when highly fluid. Not only would the many, often intersecting, apophyses more readily force their way into the country rock; the certainty of loss to the walls and roof would be increased because of direct gravitative pull. Blocks having insufficient attachment to the roof because of joints or other planes of weakness in the superstructure, would sink in the magma less dense than themselves.

Another cause of the mechanical destruction of the vault, a cause, perhaps much more important than the two cited, may be found in the special conditions of strain existing at molar contacts. The temperature of the invaded rock is raised by the adjacent magma many hundred degrees Centigrade above the temperature the rock may be assumed to have had before the intrusion began. As much as two per cent of volumetric increase could thus be produced in the solid rock close to the magma. Farther away, though still near the contact, the elevation of temperature and corresponding expansion in the country-rock would be of a much lower order. It is evident that enormous strains would be set up in the relatively thin shell of the vault bounded by the molar contact. The strains would be comparable to those observed in surface cliffs and quarries exposed to rapid but small changes of temperature, but on a much greater scale. The complex stresses induced might conceivably result in the extensive shattering and exfoliation of the country-rock.†

In the operation of all these various causes, it is highly probable that, during most of its history, a molten plutonic magma has a much greater power of rifting masses from its walls and roof than in the short closing stage of its career as such before crystallization is completed.

The opening of the magma chamber.—By the integration of relatively small effects in stoping, the chamber or space opened for the continued intrusion of a magma may be indefinitely enlarged, so long as heat and thickness of crust sufficient are supplied by the conditions of nature. Its form would be that of a downwardly enlarging compartment within the invaded formation, though a pipe-like chamber could also

* Ann. Rep. Geol. and Nat. Hist. Surv., Canada, 1887, Pt. F, pp. 131–2–3–8, etc.

† Cf. Reade's experiments, op. cit. pp. 17–28.

be produced. The time required for the formation of a chamber appropriate to a "batholith" or large stock may be great, but doubtless no greater than that posited, for example, by Brögger in the fashioning of the huge laccolithic chambers of the Christiania Region,* and certainly no greater than the time demanded for the opening of a similarly extensive chamber by mere caustic action on the molar contact. Stoping will vary in rapidity with the size of the blocks rifted. The average block from visible contacts is most probably smaller than the average block rifted during the much longer period of high fluidity in the magma. Perhaps the partially sunken blocks resting on the quartz porphyry "laccolith" near Drammen, Norway, may represent possible sizes for such blocks. They are long slabs from 250 to 1500 meters in diameter.†

A brief statement of this central idea of the stoping hypothesis has been given by Lawson in a review of certain of Brögger's writings. So far as known to the present writer, this noteworthy paragraph contains the only clear enunciation of the doctrine to be found in geological literature, and is worthy of quotation in full:

"The essential features of the assimilation hypothesis were formulated by the reviewer some years ago, before the publication of Michel Lévy's views, and urged as a satisfactory explanation of the remarkable relations which obtain between the Laurentian granites and gneisses and the upper Archæan or Ontarian metamorphic rocks. These intrusive granites and gneisses occupy vast tracts of the Archæan plateau and there seems to be no escape from the view that they bear a batholitic relation to the crust which they invaded from below. Portions of the crust were absorbed, but there are two possibilities as to the method of absorption, viz: 1. by fusion; 2. by sinking into the magma. The numerous blocks of rocks scattered through the granites lends much probability to the latter having played a part in the process. Such batholites were doubtless accompanied by laccolitic satellites."‡

It is recognized that the stoping hypothesis, like the older ones which demand the supposition of high magmatic fluidity, must meet a difficulty suggested by the last consideration. If the eruptive body was, throughout its whole history, plutonic, as is generally assumed for the world's great granite massifs, how could the roof of its chamber, when of large span, be supported? The question is of great importance, but the intended limits of this paper will not permit of its being fully dealt with, even if all the elements of the problem were at hand.

* Die Eruptivgest. des Kristianiagebietes, ii, 144 (1895).
† Brögger, op. cit., p. 136.
‡ Science, New Series, vol. iii (1896), p. 637.

The depth of the pressure-solid basement supposed to form the foundation of such magmas, the density stratification of the liquid magmas themselves, the distribution of diluting "mineralizers," the efficiency of buttresses left in the act of stoping, the possibility of progressive lateral cooling in stock or "batholith," the strength and thickness of the chamber vault, are among those elements.

The difficulty of reconciling the idea of stoping as a process extensively operative in intrusion, with the apparent necessity of postulating flotation for the crust overlying still liquid batholiths, is partly met by recognizing the influence of compression in the magmas under their heavy crustal loads. The full significance of such compression cannot, for lack of existing experimental data, be told, but, from the known analogous compressibility of glass, it is probable that the quantitative value of the compression in great depths is considerable. As we have seen, this conclusion is in no sense inimical to the possibility of stoping, since rifted blocks are under the same pressure as the magmas enclosing them.

Further, it has been seen from a discussion of Table IV, that many solid crystalline schists and sediments (staple rocks in the earth's crust) might be expected to float on the heavier gabbros when the latter are highly fluid. Reasons are given below for the conclusion that earth-magmas are, in general, arranged according to the scheme of density stratification, and that, beneath the less dense, acid magmas, as well as underlying the solid crust, there is a world-circling layer of potentially molten gabbro magma. If this view be accepted, it is possible to credit some roof-support for a large batholith to the immersion in gabbro of the bases of the walls and of large intervening pillars of solid roof-rock invaded by the batholith. The required strength of the whole roof becomes, on that supposition, of comparatively low degree, equivalent, namely, to that of the relatively small vaults between the main walls and pillars; such vaults as belong to the associated stocks so commonly believed by geologists to represent the upper portions of huge, regional batholiths. Provided that the roofs of the stocks remain intact, their chambers, filled with magma less dense than the overlying crust, will represent so many floats for the roof of the whole batholith.

Needless to say, the body of desired facts ascertained in field observations is insufficient to permit of an adequate test of these hypothetical postulates. The problem is, therefore, at present, largely indeterminate. It might, perhaps, be adequately treated by actual analytical study of type occurrences where the phenomena of nature indicate either that wholesale foundering has not taken place, or, on the other

hand, that partial subsidence of graben-blocks at fault-troughs can be proved. The former conclusion seems warranted for the very numerous smaller stocks, and the writer believes that it is in the main permissible, and even necessary, in the case of most batholithic masses.

Tests of the Hypothesis of Overhead Stoping.

The hypothesis of magmatic overhead stoping is believed, then, to be founded on a thoroughly competent geological process, one for which there is a certain amount of clear ocular demonstration in the field, namely, contact phenomena much more widely disseminated in nature than the dislocation or caustic phenomena yet proved on behalf, respectively, of the "laccolithic" and "marginal assimilation" theories. It is believed that neither of the latter theories lays enough emphasis on the normal property of internal plutonic contact belts of systematically containing large numbers of fragments from the invaded formations. The laccolithic theory suffers further from the absence of observations proving the existence of basements of country rocks for the larger granite massifs. The hypothesis of stoping and rapid sinking explains the general lack of such blocks in the central portions of the massifs, and is corroborated by the facts, going to show that, precisely under those conditions when blocks would *not* sink in the less dense magma, the latter exhibits independent evidence of being enormously weakened in its thermal, chemical, and physical (rifting and stoping) activity.

Testimony of laccoliths.—In view of the extreme improbability that one can often, if ever, expect to find the pressure-solid, or otherwise determined floor of a deep-seated magma basin,* it is of interest to question the few known laccoliths with visible floors for information as to the efficiency of stoping. Of course, the conditions for rifting and for the submergence of blocks from the roof, are much less favorable in the rapidly intruded magma of a typical laccolith from what they would be in a deeper-seated magma in direct communication with the "ewige Teufe." Some notable degree of viscosity seems necessarily assumed as characteristic of laccolith magmas. The *proved* laccoliths are all small and are surrounded on every side, except at the narrow conduit, by cold rocks, so that chilling must be much more rapid than under plutonic conditions. Nevertheless, the attempt has been made to find, in the published descriptions of type laccoliths, any statement for or against the probability of a limited amount of rifting and stoping. In such small igneous bodies, it would be

* Brögger, op. cit., p. 134.

unlikely that total digestion would destroy blocks fallen from the roof. They might, therefore, be looked for on the floors. So far, the writer has discovered no evidence on the point in any of the monographs. The reasons are not far to seek. Very few floors of laccoliths are actually exposed. It is probable, too, that in many instances an observer would have difficulty in distinguishing blocks torn out of the floor from those sunk thither from the roof. Gilbert,* Jaggar,† and others describe fragments at levels above the floor, but do not directly raise the question as to how they were held suspended within the magma. In the laccoliths of the Henry Mountains, the unusually low densities of the invaded sandstones and shales are such as to warrant the belief that fragments of these rocks really floated in the magma. The specific gravity of the Mt. Hillers trachyte, for example, is at 20° C., 2·63. Using Delesse's ratio of 4 per cent of net volumetric increase in the passing of trachyte from rock to glass at the same temperature, and then applying Barus's fusion curve, it follows that the trachyte magma would have, at 1400° C. and one atmosphere of pressure, a specific gravity of 2·34. From Reade's expansion coefficient for sandstone we can calculate the specific gravity of the unaltered invaded sandstone at 1400° C., while conceived as still solid and obeying the normal law of thermal expansion for sandstone. The decline in specific gravity is from 2·15 to 2·06. The corresponding decline for the contact metamorphosed sandstone is from 2·48 to 2·38. The values show a high probability that the average sandstone fragment would float in the magma at least until it was altered nearly to the maximum observed near Mt. Hillers. This conclusion raises the suggestion whether density may not control the formation of some laccoliths in a manner somewhat different from that hypothecated by Gilbert‡—a subject evidently remote from the purpose of these pages.

Jaggar has described large blocks of Cambrian strata as immersed in the laccolithic porphyries of the Black Hills and explains them as due to "excessive doming." Yet it is conceivable that they may owe their present positions to high magmatic viscosity, the magma freezing as they were in the act of slowly floating upwards from the floor or sinking from the roof of the laccolith.

So far, then, laccoliths have given only negative evidence in the test of the stoping hypothesis for plutonic magmas, and, perhaps in the nature of the case, they can never be of great value in determining the truth of the hypothesis.

* Op. cit., p. 66.

† The Laccoliths of the Black Hills, U. S. Geol. Survey, 21st Ann. Rep., Part III, 211 (1901).

‡ Op. cit., p. 75.

Abyssal assimilation.—Other tests of the hypothesis in addition to those of direct laboratory experiment and field observation, are obviously suggested when we leave the igneous contact and consider the fate of the submerged blocks.

Assuming that overhead stoping is competent to form in the earth's crust chambers of the size represented in stocks and "batholiths," the inquiry leads perforce into the problem of magma genesis. If so much mechanical loss has been suffered by the formations invaded by a given magma, what effect will be wrought on the composition of that magma by the submergence of the corresponding fragmentary material? How far will such blocks sink? What is their future history? If it can be shown that the foreign material is to a magma what food is to an animal, does it follow that there will be the equivalent of digestion and, by diffusion, still more intimate assimilation of the country-rocks by the magma? At this point, we must enter the region of theory on the origin of all igneous magmas, a region certainly beset with great impediments to progress. Only so far as these general considerations seem to call for immediate treatment as a further test of our hypothesis, and then but in skeleton outline, does it seem advisable to follow out the subject at this time. It is felt that no other special apology is needed for thus venturing into what must always remain speculation to so large an extent, for *any* theory of intrusion must be similarly correlated with the chemical and physical characters of igneous rocks.

As experiment has thrown much light on the mechanics of intrusion, it may also help deductive reasoning in determining the probable future of submerged blocks. Whether any block would be permitted to sink thousands of feet or several miles from its former niche in the vault, it is probably impossible to say. The locus of denser, though still liquid, layers of magma in which the block would float, cannot be foretold. The block might even sink to the deep level of pressure-solid magma, if it be not already digested on its downward journey. In either case it must undergo an increase of pressure and, with the greatest probability, an increase of temperature.

The added pressure would have, according to the experiments and field studies of Barus, Doelter, Daubrée, Fouqué, Michel Lévy and others, the secondary effect of increasing the capacity of the magma in retaining water and other solvents, even at very high temperatures.* So important are other experiments in this connection that a brief résumé of certain results accruing from them must be given.

* Among the more recent papers, cf.: C. Barus, this Journal, xxxviii, 408, (1889) and xli, 110 (1891). C. Doelter, Centralbl. f. Min., etc., 1902, p. 550; and Tscher. Min. u. Petrog. Mitth., xxi, 218 (1902).

The solubility of rock-forming minerals in silicate magmas has been shown by fusion experiments to depend on *a*, the temperature of the magma; *b*, the chemical composition and fluidity of the magma; *c*, the fusibility of the minerals; and, *d*, on pressure. Doelter has been able to prove that, under one atmosphere of pressure, all the common types of rock-forming minerals are completely soluble in certain representative magmas at temperatures only slightly above those of their respective consolidation points. These magmas were made from granite, obsidian, common basalt, limburgite, phonolite, foyaite, leucite basalt, leucitite, hornblende andesite, and nepheline basalt—a magmatic range so wide as to demonstrate the practical certainty that all silicate magmas have similar solvent properties. He further shows that the melting point of a silicate rock occurs at about the average temperature of fusibility of its constituent minerals. Long before, Bischof easily dissolved clay-slate in fluid lava, using a bellows furnace for fusion.* These important deductions from laboratory investigations correspond to the facts of outdoor nature. Well-known practical examples may be found in the fused and greatly corroded granite inclusions in the basalts of the Auvergne; and, again, in the complete disappearance, by fusion, of the "floating islands" in the caldera of Kilauea.† The high fluidity of the normal plutonic magma would likewise facilitate the complete solution of foreign fragments, as experimentally proved by Doelter.

It is true that the direct influence of pressure tends to elevate the melting points of silicate mixtures, though probably not in a degree proportional to the amount of the pressure.‡ Yet that effect on the solvent power of the magma may be much more than counterbalanced by the indirect effect of pressure in retaining water and other solvents. Once molten, pressure tends to keep silicate magmas molten, since it lowers the temperature point of consolidation.§ In determining the solvent power of a plutonic magma, temperature furnishes here, as in fixing the melting-point, the "coarse adjustment," as pressure furnishes, of itself, the "fine adjustment."

In conclusion, then, it seems legitimate to regard the conditions of the abyssal portions of plutonic magmas as conspiring toward the perfect digestion of a submerged foreign rock fragment during all the time of intrusion except during the short period preceding final consolidation. Even so uncompromising an opponent of the theory of contact digestion by stock magmas as Brögger admits that such assimilation can be, in

* Chem. u. Phys. Geol., Supplement, p. 98 (1871).
† J. D. Dana, Characteristics of Volcanoes, p, 176, New York, 1891.
‡ Doelter, Tscher. Min. u. Petrog. Mitth., xxi, 221 (1902).
§ Oetling, op. cit., p. 370.

the greater depths, exceedingly important, "ausserordentlich bedeutend."* Several cases have been described in which even marginal assimilation at great depths has affected batholithic magmas, though, as we have already seen, such cases are exceptional.

Since it is probable that magmas are more or less completely saturated solutions,† there would doubtless be a volumetric increase on the fusion of each block at whatever depth it attained, an increase comparable to that demonstrated in fusion experiments at 1 atm. of pressure. The question at once arises as to what compensation can be made for the increased bulk of rock-matter below the earth's surface incident to abyssal assimilation on a large scale. Two possibilities suggest themselves in the face of the hydrostatic problem involved. Either volcanic outflow elsewhere, or secular upheaval in the region, would satisfy the conditions. The latter would seem to be more likely of fulfillment in regard to stocks and batholithic intrusions generally. It is to be noted that magmatic stoping would tend to weaken the earth's crust immediately above the intruding body, and there secular elevation of the surface would be particularly looked for. There may, in this way, be found one cause of the huge buckles filled with the "central granites" of alpine mountain chains. This implies that the doming of the great intrusive masses of the Christiania Region, attributed by Brögger to laccolithic injection, may, in reality, be due to this crustal weakening and buckling by magmas working up from the "ewige Teufe." But, at present, it must remain only the suggestion of a possibility, as the writer has no personal knowledge of the region.

It is, moreover, worthy of inquiry whether this sort of live energy of intruding granitic magma may be responsible for many of the well-known cases where the secondary structure-planes in the invaded formations wrap around their respective intrusive bodies. Examples are seen in the highly developed peripheral cleavage and schistosity parallel to the outlines of such magmas in the Rainy Lake region,‡ in the Black Hills,§ and in the Sierra Nevada.‖ Such structures would certainly be produced by the force of magmatic expansion, provided that force be sufficient in amount, for it must be exerted always normal to the chamber-walls.

* Op. cit., iii, 350 (1898).

† Lagorio, Tscher. Min. u. Petrog. Mitth., viii, 504 (1887). Cf. Delesse, Bull. Soc. Géol. France (2), iv, 1393 (1847).

‡ Lawson, Ann. Rep. Geol. and Nat. Hist. Survey, Canada, 1887, Pt. F, map.

§ Van Hise, 16th Ann. Rep. U. S. Geol. Survey, Part I, 1894–5, pp. 637 and 815.

‖ Turner, 17th Ann. Report U. S. Geol. Survey, Pt. I, 1895–6, p. 555.

Formation of compound magmas by abyssal assimilation.—To return to the main line of argument. If abyssal assimilation by a magma be a fact, that magma must become more and more mixed with the products of assimilation. Any eruptions during, and subsequent to, the mixing might be expected to show indications of the gradual alterations of the magma in the normal case where magma and invaded formations have different chemical composition. The writer believes that the sequence of eruptive-rock types derived from such a heterogeneous magma would not be directed simply by the assimilated product, but would follow definite physical and chemical laws which govern heterogeneous magmas however formed. These laws are embodied in the modern principle of differentiation. By differentiation, the irregularly constituted and compound magma of assimilation becomes definitely split up into submagmas which may, on eruption, represent actual igneous rocks visible at the earth's surface.

Differentiation of compound magmas.—Numerous recent discussions and summaries of the well established facts on which the doctrine of differentiation is based, render unnecessary in this paper a restatement of the evidence. No other principle has yet been evolved which explains so satisfactorily the phenomena of consanguinity; the fact of type-constancy, in the midst of variety, among the eruptive rocks of the world; the normal order of eruption; the phenomena of complementary dikes; the border facies of many stocks; and the existence of basic and acid segregations. Michel Lévy himself, so long a powerful and adverse critic of the differentiation theory, has of late been won over to a recognition of its value in explanation.*

The consequences of our hypothesis demand that some emphasis be laid on the probable nature of the differentiating process involved in the splitting up of the abyssal magma. Without wishing to be understood as denying the probability of several other causes for differentiation, the writer will note those conditions which, in his opinion, favor one cause in this particular instance rather than any other.

Each year new facts are accumulated, going to prove the existence, at no great depth below the earth's surface, of a general ferromagnesian magma, and recent theories of the igneous rocks have thus returned in one point to the older views of Bunsen and others. As yet it cannot be affirmed that this or any other subcrustal magma is normally solid by reason of pressure and only locally fluid by the local release of the pressure. Nor can it be certain that a rock fragment, stoped out from the vault of an intrusive body, would sink necessarily

* Bull. Soc. Géol. France (3), xxv, 326 (1897).

to a magma layer as dense as itself. Yet it appears not to stretch the probabilities too far, to assume that pressure solidity would not characterize, in general, the lower basic part of a magma basin above the level where a normal siliceous sediment or schist block would come to rest. As a rule, that would mean that the magma must become acidified by the assimilation of the more siliceous rock. The equilibrium would thus be disturbed and an upward current of the locally modified magma would be set up. Such action would be specially notable in the case of gabbro and peridotite magmas intruded into any staple member of the fundamental crystalline schist complex. Downwardly-directed currents in the magma would also be developed during the sinking of the blocks.

Such currents would tend toward the rapid formation of horizontal homogeneity at the various levels in the chamber, and of vertical heterogeneity (on a larger scale than the similar heterogeneity expected by the older assimilation theory), governed by the law of increasing density with depth. The more acid layers would concentrate at the top, the more basic remain at the bottom, of the magma basin. The layers would, it is believed, be more or less definitely composed by the laws of differentiation operating by diffusion. It is certain that diffusion is aided by agitation,* and in the density currents and those induced by the falling blocks we have two efficient causes for agitation. Further, Braun and Alexejew have shown that enhanced pressure stimulates the differentiation of a complex magma into distinct fluids.† Increased pressure is, as we have seen, felt in the magma by the conversion of each fallen block into liquid rock. Finally, certain other facts of recent discovery seem to bear out the conclusion that differentiation by the gravitative effect actually occurs. Morozewicz cites instances of the process in his fusion experiments and in the study of glass furnaces.‡ Doelter has stated that such results adhere to special cases both in his own experiments and in those of the Russian investigator; yet their significance is still great, since they agree with Gouy and Chaperon's theoretically deduced principle of gravitative stratification in saline solutions,§ as well with some positive field observations. For example, Sir A. Geikie describes the separation of a lower layer of picrite and an overlying layer of olivine basalt in the same lava-flow, and finds it probable that similar differentiation has taken place in basic sills.‖ Becker's physical researches¶ and Rosenbusch's conclusion from more purely petrological consid-

* Becker, this Journal, iii, 25 (1897). † See Becker, op. cit., p. 32.
‡ Tscher. Min. u. Petrog. Mitth., xviii, 170, 233 (1898).
§ Ann. de chimie et de physique, ser. vi, vol. xii, 1887, p. 384.
‖ Ancient Volcanoes of Great Britain, London, 1897, vol. i, pp. 419 and 442, and vol. ii, p. 310. ¶ Op. cit., p. 37.

erations* are accordant with the hypothesis. An interesting statement of it is given by Walker.† In view of the agitation produced by the powerful currents set up under the special conditions inferred by the stoping and sinking of blocks, it is also probable that gravitation would be capable of stratifying the material directly dissolved by a magma from the walls of its chamber. Secondary and less important causes may explain the existence of complementary dikes, basic borders and segregations.

The eruptive sequence.—The particular kind of igneous rock erupted from the magma basin will evidently depend on the level from which the magma is drawn. In general, surface, hypabyssal, and even plutonic bodies may be expected to originate in the upper portions of the basins. If the original magma be more acid than the invaded formation, the former would probably, in its upper part, be modified by abyssal assimilation in but subordinate degree, and the sequence of the eruptions would normally be from acid to basic. If, on the other hand, the original magma be more basic than the invaded formation, that magma would be specially altered in the upper part of the basin and a long continued series of eruptions would show the order of basic to acid. Two different petrogenic cycles are thus possible. By thorough solidification of the upper layers of the magma (accompanied by secular denudation at the earth's surface), and renewed eruptivity, the petrogenic cycle for an area might be repeated as a whole or in part.

In deciding as to which of the two cycles should, by our hypothesis, be most commonly represented in nature, it is clear that each eruptive field and petrographic province should be studied by itself and the results correlated for the world. The impossibility of such complete correlation at the present time need not discourage the attempt to test our hypothesis by such generalizations as may now be made. Can we arrive at a decision as to what is the average invaded formation and what the average primary magma of the earth?

The first question may be answered with a high degree of probability for about one-third of the earth's surface, namely, the continents and the immediately adjoining belts of the sea-floor. In those areas, the greatest volume of rock above the average isogeotherm of rock-fusion is doubtless made up of the acid crystalline schists. The composition of the suboceanic crust generally is almost entirely a matter of speculation. The second question is beginning to assume a most prominent place in petrogenic theories. On the continents, the staple plutonic rock is the acid granite; the staple volcanic eruptive,

* Mikros. Physiographie, etc., ii, 552 (1896).

† This Journal, vi, 410 (1898); cf. Vogt. Zeit. für prak. Geol., 1893, p. 279.

basalt. On the oceanic areas, the staple visible eruptive is the basic, and necessarily volcanic, basalt or allied augite andesite. These facts of relative volume in igneous output agree with the views derived from chemical considerations long ago by Bunsen,* and more recently by Michel Lévy† and others. Two fundamental magmatic types, the alkaline granitic and the ferromagnesian, dominate among the world's igneous rock-types. The fact that they do exist is independent of theory. Certain other facts point to the conclusion that the supply of the ferromagnesian magma available for eruptive purposes is much greater than that of the alkaline magma.

In those conduits where the escape of igneous magmas from the earth's interior to the surface takes place to such an extent as to build large volcanoes, we should expect the sequence of eruption to be completed by effusions of lava more nearly representing the original or primary magma than the antecedent flows. The reasons for this are: first, that assimilation in the immediate vicinity of the vent would, in that late stage in the development of the volcano, have progressed so far as to have enlarged the conduit to a size suitable to a large cone; secondly, that the vent would, by the long continuance of the volcano's activity, have become freed from the products of the assimilation; and, thirdly, that the latest flows would be derived from the original magma practically unaffected by assimilation. Now, it is a significant fact that the latest extrusive product of the great majority of the largest volcanoes, such as Etna, Fusiyama, Chimborazo, Cotopaxi, Kilima-Njaro, etc., is, so far as known, either basalt or augite andesite.

Not less important is the equally indisputable fact that the greater fissure-eruptions of the globe give birth to only one kind of lava, again basaltic. The familiar examples in Iceland, northwestern Europe, India, the northwestern United States of America, and the Hawaiian archipelago, tell no uncertain story concerning the nature of the vast reservoirs from which they have derived their enormous volumes of lava. The more acid flows which occur in any of these regions are insignificant in bulk compared with the total basic output. The question is quite open whether the former are not the product of differentiation acting on the primary basaltic magma influenced by the assimilation of the continental rocks, which are characteristically more acid. Further, we should expect assimilation to be less active in determining the composition of fissure eruptives than in preparing the secondary magmas erupted in volcanic cones or injected in intrusive forms. From the nature of the geological dynamics rendering possible the rapid expulsion of

* Pogg. Annalen, lxxxiii, 197. † Op. cit., p. 368.

the voluminous flows at master fissures, it is clear that the corresponding magmas had relatively easy access to the surface and had not to work their own way through the earth's crust. The plateau lavas therefore merit particular notice in the search for the general earth-magma or magmas. It is doubtful that enough emphasis has been placed on the volume, relative abundance and mode of geological occurrence characterizing the different eruptive types, in the published discussions on the origin of igneous rocks. Those elements must always be of prime importance in the solution of the problem of assimilation.

For different reasons excepting that derived from the enormously greater abundance of basaltic lavas on the earth, Dutton came to this same conclusion as to the nature of the "primordial matter." He has rightly dwelt on the fact that basalt is a "synthetic or comprehensive type of rock." His theory of the derivation of other igneous rocks by simple fusion of sedimentary formations derived in their turn, by weathering, from the "primordial matter," takes insufficient account of the facts of differentiation learned since 1880. Yet his theory has a suggestive relation to the one proposed in these pages.*

It is not essential to our present purpose to decide on the question whether the acid-alkaline magmas of the continents represent the more or less altered primal material segregated on the original crust of the earth, or are the product of the secular alteration of continental sediments derived from the synthetic basaltic magma—if such decision be really possible. The main facts of igneous rock distribution and the *a priori* conception that alkaline magma must float on the ferromagnesian magma, lend themselves to the belief that a gabbroitic magma underlies the surface of the whole earth at a depth not too great to prevent its energetic eruption. If, during such eruption, overhead stoping and abyssal assimilation accompanied by differentiation, occur, the gabbroitic magma will be modified and a normal world sequence from basic to acid be established. In spite of the numerous exceptions to this order in nature, a fair judgment on the case must reach the conclusion that such a law governs intrusive bodies at least. We have already seen reasons for believing that the order may, on the same hypothesis, be abnormally reversed for plutonic masses, and *should* be reversed for the greater volcanic rock-bodies. Granite, on account of its superior stoping power and low density, compared with the basic plutonic rocks, should be the more common among those irruptives exposed by denudation at the earth's surface.

* Rep. High Plateaus of Utah, p. 125 ff., Washington, 1880.

Summary.

A general summary will be of value in gathering up the various threads of the argument tending to support the hypothesis of magmatic overhead stoping. The fundamental facts of the field and laboratory will be briefly recapitulated. There will follow a résumé of the tests which have so far been applied to the hypothesis. In those tests, it is believed, may be found a material strengthening of faith in the hypothesis, since it is seen that it explains several principal petrological facts not necessarily, or, at least directly, connected with the idea of stoping.

The facts of the field.—1. Many, and perhaps most, stocks, so-called "batholiths," and "central granites" show an almost entire lack of sympathy between the structural planes in the invaded formations and the form of the intrusive body.

2. For some of these bodies there is conclusive evidence that their respective magmatic chambers were not prepared for intrusion by circumferential faulting. For the great majority of the remainder, the indications for such faulting is negative.

3. For many, perhaps most, stocks and "batholiths," the combined contact phenomena demonstrate some kind of active assimilation of their corresponding country rocks by the respective magmas.

4. In the normal stock and "batholith," there are usually: a decided lack of any enrichment of the endomorphic zone by substance dissolved from the invaded formations; a general freedom from foreign inclusions in the interior, together with a characteristic abundance of angular enclosures near the contacts; an exceedingly sharp line of contact with the country rocks; equally sharp contacts of the foreign fragments and their respective hosts; lack of direct sympathy between the composition of the intrusive bodies and their respective country rocks; a general high degree of homogeneity in the composition of the igneous body; the common occurrence of many long and narrow apophyses from the igneous body, indicating strong liquidity at the time of the intrusion of the main igneous mass.

5. Field relations, coupled with a comparison of the chemical and mineralogical characters of igneous rocks the world over, show well established and wide reaching laws of magmatic differentiation.

6. Isolated observations in nature prove that solid rocks may sink in molten lavas because of differential density; others show that fragments of solid rock can be more or less completely dissolved in molten lava.

The facts of experimental research.—The experiments of Barus, Doelter, Daubrée, Delesse, Cossa, Bischof, Oetling, Morozewicz and others show:

1. That representative natural or artificial silicate mixtures at ordinary atmospheric pressure become thinly molten at a temperature only slightly above that of solidification;

2. That, in every instance, a great increase of volume characterizes the change from the solid to the liquid state;

3. That, with strong probability, this volume increment and resulting density decrement are so far preserved in rock magmas under plutonic conditions as to forbid the flotation of blocks of the average country rock immersed in the average magma in depth (other allied conclusions have been already summarized on pages 279 and 280);

4. That the chief rock-forming minerals are soluble in all of the melted silicate mixtures yet investigated, and at the temperatures ruling when those mixtures are thinly molten;

5. That pressure aids the solubility of minerals indirectly by retaining in the magma, water and other solvents, but retards it, probably in much less degree, by raising the temperature of fusion for silicate minerals.

6. That there is evidence of differentiation in molten magmas by gravitative effect.

The tests of the hypothesis of overhead stoping and enlargement of magma chambers.—Reasons are given for concluding that:

1. The cause cited for overhead stoping is quantitatively sufficient for the majority of stocks and "batholiths."

2. The presence of foreign inclusions at internal contact belts of stocks and "batholiths," and the detailed phenomena associated with those inclusions, are facts of nature expected on the hypothesis. It is implied that the removal of blocks from the chamber-vault is comparable to the work of a river. The active corrasion of a stream in its youth is rapid and corresponds to the rapid stoping of an intrusive body in its first long stage of high temperature and fluidity. The feeble corrasive power of a stream in its old age corresponds to the diminished stoping activity of the magma in its viscous, solidifying period. The conclusion is drawn that, under the energetic conditions of high liquidity, a magma may open, in the invaded formation, a chamber of a size appropriate to a stock or "batholith." Independent grounds exist for believing that ample time is allowed by granitic intrusion for such integration of relatively small effects.

3. The corollary of abyssal assimilation has many experimental and other data in its favor and is backed up to a greater

degree by such facts, than the theory recognizing caustic assimilation as occurring merely or chiefly on main vault contacts.

4. The hypothesis is supported by a survey of the facts of magmatic differentiation. It is believed, further, to give the best explanation of the petrogenic cycles yet found illustrated in nature, and to explain with special force the normal eruptive sequence. At the same time, the hypothesis is not weakened by the known cases of the reversal, or other modification, of that order of eruption.

5. The hypothesis accords with the facts known with regard to other kinds of igneous intrusion. Even in the case of those great granitic massifs organically associated with master-lines or zones of dislocation (e. g., the tonalite and the "Judicarienlinie" of the Tyrol), the magma chamber may have been principally opened by overhead stoping. The same process may similarly enlarge the deep-seated cross-section of a volcanic neck. Yet no one can deny its practical insignificance in the intrusion of sheets or dikes, nor, for obvious reasons, does that fact injure the strength of the proposed hypothesis when dealing with much larger igneous bodies. The latter must be longer molten by reason of their size and direct communication by means of convection and other currents with the earth's interior. The same remark made concerning dikes and sheets applies also to the proved laccoliths, although it is probable that, in a very limited way, laccolithic magmas may carry on stoping and therewith assimilation in their hot interiors. Dikes, sheets and laccoliths are but offshoots of the greater magma-basins with which the hypothesis is concerned.

Among the further tests needed comes first, perhaps, that for further experimental investigation of molten rock magmas under high pressures. It should be particularly determined whether the carbon and silicon compounds show analogous behavior under high pressures, as they certainly do at ordinary pressure and at temperatures below, at, and above their respective melting-points. Fusion experiments additional to those of Barus and covering a range of igneous rock types and at varying high pressures, would be still more valuable than the indirect method of comparison between hydrocarbons and silicates.

General Summary on the Mechanics of Intrusion.

In the foregoing pages, the writer has briefly compared the hypothesis of overhead stoping in the formation of magma chambers with the "laccolithic" theory of crustal displacement and with the theory of marginal assimilation of invaded formations. Since the question is intimately connected with that of the origin of the igneous rocks, it might be considered

necessary to compare as well the effect of the rising of the isogeotherms in fusing stratified formations. This paper has already assumed such proportions that that subject may well be left in abeyance. Suffice it only to point out that the igneous rocks of most intrusive bodies are demonstrably exotic and have penetrated considerable distances vertically into their invaded formations which are *not* fused because of the rising of the isogeotherms. The fusion of rocks by this method cannot, therefore, of itself explain the formation of the actual chambers opened to human sight by secular denudation.

One must feel a certain hesitancy in taking a definite position on a matter of such fundamental importance; yet a categorical statement may bring into sharper relief the main conclusions to which the writer has come. Dikes, sheets, laccoliths, "bysmaliths," and perhaps a few of the smaller stock-like, plutonic bodies are conceived to be due to crustal displacement *permitting* intrusion; in the preparation of the greater and much more important subterranean magma chambers, marginal assimilation is believed to be a true cause, but, in the large, to be quite subordinate to magmatic overhead stoping, while bodily crustal displacement is in but indirect control inasmuch as it only localizes the areas where stoping is to form the chambers; and abyssal assimilation of stoped-out blocks, supplemented by the subordinate marginal assimilation, may be held responsible for the preparation or notable modification of magmas, whence come, through differentiation, most of the igneous rocks of the globe. The plateau-basalts would appear to represent the one widely distributed kind of magma not essentially affected by assimilation.

Geological Survey of Canada, Ottawa, Canada.

Art. XXX.—*Brachiosaurus altithorax, the largest known Dinosaur;* by Elmer S. Riggs.

The writer some time since called attention* to a partial skeleton of an herbivorous dinosaur of unusual proportions obtained from the Jurassic of western Colorado. On account of the difficulty in distinguishing between a number of genera already referred to the Sauropoda, it did not then appear advisable to further complicate the problem by proposing a new generic name. But as the unique characters of this animal have become more and more evident it now seems desirable to give it a name, even though it ultimately be found to fall within one of the three or four uncertain genera proposed by Marsh and Cope. The term *Brachiosaurus altithorax* is therefore proposed in recognition of the great size and unusually long humerus of this specimen.

The generic characters are: humerus longer than femur; thorax unusually deep; centra of posterior thoracic vertebrae longer than wide; anterior caudal vertebrae amphicoelian and their diapophyses not vertically expanded; coracoid elongate in direction of scapular suture and having glenoid cavity facing antero-externally.

The specimen upon which this genus is based was collected by the Field Columbian Museum paleontological expedition of 1900, from the Grand River valley of western Colorado. Credit for its discovery is due to Mr. H. W. Menke of this Museum. The specimen consists of the humerus, coracoid, femur and ilium, all from the right side; the sacrum, seven thoracic and two caudal vertebrae, together with a number of ribs and other bones. The parts were, with the exception of the ribs, preserved in their relative positions, and as the specimen was isolated there can be no question that all belonged to one individual.

The distal end of the humerus was exposed, broken and displaced as surface fragments. Associated with its proximal end was the fairly well-preserved coracoid. Some fifteen feet farther along the hillside the sacrum and pelvic bones appeared lying with spines downward. Two partially weathered caudals were closely connected with the posterior end of the sacrum. The thoracic vertebrae stretched forward in an unbroken series with the ribs scattered on either side and more or less displaced. Up to this point there seemed every reason to hope that the whole anterior portion of the skeleton would be found. But at the end of the seventh presacral vertebra the thin clay

* Science, April 5, 1901.

stratum in which the bones were imbedded "pinched out" and was replaced by a thickening of the massive ledge of sandstone which overlaid it. The presence of pebbles at the base of this sandstone, as well as the uniform direction in which the ribs were displaced, showed that the anterior portion of the skeleton had been carried away by the action of a water-current before it had become thoroughly imbedded.

When the surface fragments of the humerus had been carefully collected and fitted to the portion still in position, that bone stretched out to such an unheard-of length that the writer was for the time convinced that it must be a crushed femur. This conclusion was given additional weight by finding, soon after, a well preserved femur of almost identical length. However, when removed from the matrix in the laboratory and the two compared, all doubt was removed by the characteristic form of the head of the humerus as well as the presence of a well defined deltoid crest.

The length of the humerus and femur, together with the immense size of the thorax, at once establishes the fact that this is the largest and longest-limbed of all known land animals, as well as the only dinosaur known to science in which the humerus is longer than the femur. Assuming that the lower fore-leg bones were proportionately long, we have to do with a creature whose shoulders were carried far above his hips and whose fore-legs played a more important part than the hind ones. Such proportions at once suggest arboreal food-habits. Instead of rearing upon the hind legs and supporting itself by means of a ponderous tail, as were the evident habits of *Brontosaurus* and *Diplodocus*, this animal may from sheer length of limb have been able to browse at will upon the foliage of tree and shrub. What were the proportions of the neck can only be conjectured; to be consistent with the proportions of body and limbs it must have been long and flexible. The short spines and the slight processes of the anterior caudals show that the tail was much reduced both in size and in length. This then was the giraffe among dinosaurs, just as *Claosaurus* was the kangaroo.

Description of Skeleton.

The humerus is somewhat crushed antero-posteriorly and twisted so that the head and distal end are brought into the same plane (fig. 1). The surface of the distal end has flaked away in the process of weathering to a firm chalcedony core. In proportions the humerus approaches more nearly to that of *Diplodocus* than to any other well-known American genus. The head is considerably expanded, forming a rounded prominence

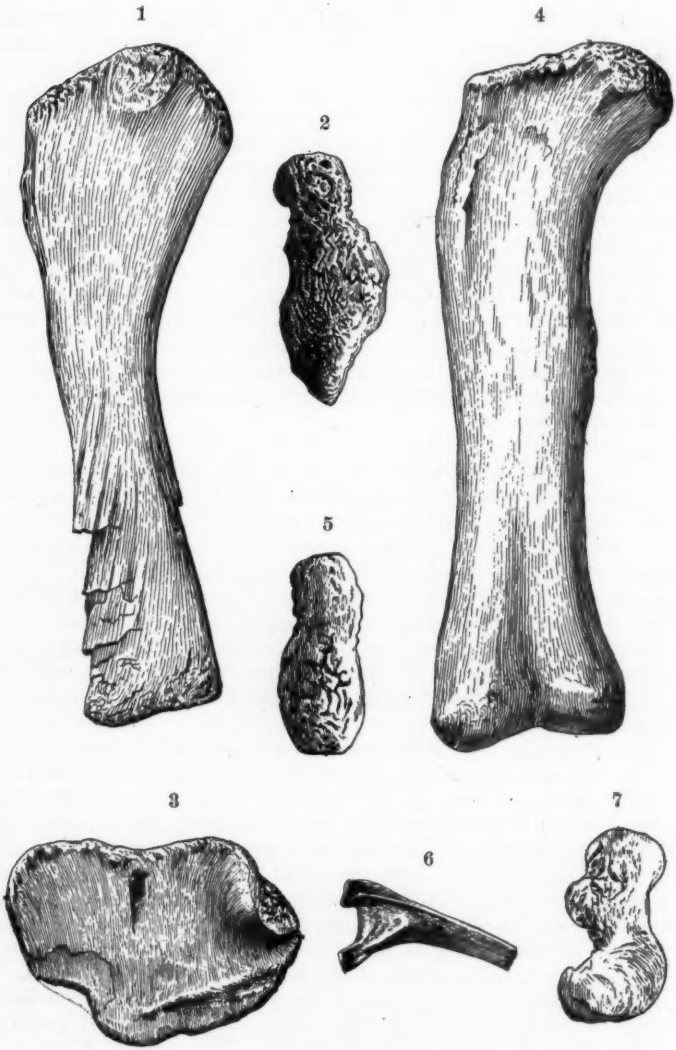
especially conspicuous in its posterior aspect (fig. 2). The great tuberosity is stout and rugose; its proximal surface meets the lateral margin of the shaft in a pronounced angle. This angle is not produced posteriorly to enclose a fossa as in *Morosaurus*. The mesial border below the head is drawn out into a rather thin margin, but roughened for muscular attachment. The deltoid crest is partially broken away, but was evidently prominent. Its base forms, with the anterior surface of the shaft, a broad and shallow concavity. Midway between the deltoid crest and the great tuberosity is a second rugose surface evidently for insertion of other shoulder muscles. The epicondylar ridge is entirely lost owing to the weathering to which the distal end has been subjected. The direction of the bone fiber on the lateral margin indicates that it was quite prominent. All traces of rugosity have likewise disappeared from the articular end, indicating that the humerus was probably some inches longer than it now appears.

The coracoid is a less massive bone than that of *Brontosaurus* (fig. 3). It is elongate antero-posteriorly, rounded below and straight at the coraco-scapular suture. The glenoid articular surface is directed outward as well as forward, a feature noted in no other Sauropod genus. The antero-inferior surface is thick and rugose near the glenoid cavity, from which it is separated by a narrow notch only. The inferior border becomes gradually thinner and its rugose character disappears midway between the glenoid cavity and the anterior scapular border. The marginal concavity noticeable in the specimen at this point is partially due to crushing from contact with the head of the humerus while in the matrix.

The femur is well preserved though somewhat compressed antero-posteriorly (fig. 4). Regardless of its great length this bone is quite as stout in the shaft as that of *Brontosaurus*, though the articular ends are proportionately less expanded. The lateral surface of the shaft has a prominent convexity one-fourth of its length below the great trochanter. A marked rugosity, possibly for the insertion of one of the gluteal muscles, extends downward from the great trochanter to this point. The fourth trochanter* forms a rugose prominence on the posterior margin of the shaft, as in all of the Sauropoda.

The presacral vertebrae are of the pronounced opisthocoelian type. They are distinguishable from other Sauropod genera by the unusual length of their centra. This, in the first presacral, is slightly greater than the breadth; it gradually increases in the succeeding members of the series until at the seventh it exceeds the breadth by one-fourth. The centra

* Dollo, Bull. d. Mus. d. Hist. Nat. d. Belgique, Mars, 1883. Osborn, Memoirs of Am. Mus. of Nat. Hist., Part V.



BRACHIOSAURUS ALTITHORAX.

Fig. 1. Posterior view of right humerus.
Fig. 2. Proximal end of same.
Fig. 3. Lateral view of coracoid.
Fig. 4. Anterior view of right femur.
Fig. 5. Proximal end of same.
Fig. 6. Posterior view of proximal end of a thoracic rib.
Fig. 7. Distal end of femur.

are deeply hollowed by lateral cavities. The whole character of their sculpturing tends toward a lightness bordering upon fragility. In this particular they are approached most nearly by the vertebrae of *Diplodocus*.

The sacrum is composed of four firmly coalesced vertebrae. Its most distinctive feature is its great breadth in comparison with its length. The measurement across the anterior end of the transverse processes is one-fourth greater than that of the posterior end and one-third greater than the type specimen of *Brontosaurus*. The first sacral rib arises from the anterior end of the centrum and is relatively unimportant. The second arises from the whole length of the centrum and is by far the strongest of the series. Its iliac articular surface is much expanded and marks the axial point in the sacrum. The third and fourth sacral ribs arise from the anterior half of their respective centra. As neither the sacral nor presacral vertebrae have yet been removed from the matrix, the description of their spinal elements will be deferred until a future publication.

The anterior caudal vertebrae are amphicoelian in form and relatively small in comparison with those of other Sauropoda. The anterior faces of the centra are more deeply concave than the posterior faces. Since the vertebrae were found lying upon their sides in close apposition with the sacrum, the marked posterior concavity can hardly be attributed to distortion. Unfortunately the spine in caudal I is not preserved. In caudal II the neural arch is as simple as in caudal VIII* of *Brontosaurus* and the spine is scarcely as long. There is no trace of lateral cavities in the centra, or of the broad vertical plates developed from the diapophyses in that genus. On the contrary, these lateral processes are simple, peg-like prominences slightly flattened vertically. The zygapophyses are imperfectly preserved in this specimen, but were apparently slight. The neural spine is short, stout, laterally compressed at the middle but expanded into a rugose knob at its extremity.

The unusual length of the ribs bears evidence of the immense thorax of this animal. In the mid-thoracic region they measure fully nine feet (2·745^{m}) in length. The capitulum and tuberculum are almost equally developed and widely separated, to give the firm anchorage necessary to the great length of the ribs (fig. 5). In some instances the attachment is strengthened by a second tubercle on the posterior surface of the head similar to that figured by Marsh† in the cervical ribs of *Apatosaurus*. The anterior surface of the shaft below the head is perforated

* Caudal VII according to Marsh's restoration.
† The Dinosaurs of North America, p. 167.

by a large foramen which leads to an internal cavity in the shaft.

Measurements.

	M.
Humerus, length parallel to axis	2·04
" greatest breadth of proximal end	·65
" thickness of head antero-posteriorly	·28
" least breadth of middle of shaft	·24
" distance from angle of great tuberosity to upper margin of deltoid crest	·51
" length of deltoid crest	·24
Femur, length parallel to axis	2·03
" breadth of head and great trochanter	·59
" breadth at fourth trochanter	·43
" breadth at distal end	·58
" distance from head to upper margin of fourth trochanter	·78
Coracoid, greatest breadth	·87
" inferior border to scapular margin	·54
" glenoid margin to foramen	·34
Presacral I, length of centrum	·39
" I, breadth of centrum	·37
" VI, length of centrum	·43
" VI, breadth of centrum	·35
Sacrum, breadth at second transverse process	1·12
" breadth at fourth transverse process	·88
" length of the four centra	·975
Thoracic rib, length	2·745
" " breadth across capitulum and capitellum	·54
Caudal II, height over all	·60
" " transverse breadth of centrum	·32
" " length of centrum	·155
" " height of spine above centrum	·32
" " height of spine above zygapophyses	·18

Relationships.

There have been four genera referred to the Sauropoda whose validity may be more or less called in question. These are *Atlantosaurus* and *Apatosaurus* Marsh, and *Camarasaurus* and *Amphicoelias* Cope. Some of these genera are certainly valid, others probably synonyms. The fact that three of the four are based upon scattered parts of skeletons of which no two have enough in common to make correlation certain, complicates the problem. Added to this is the uncertainty as to whether the type specimens represent one individual or more than one.

The genus *Camarasaurus* has usually been regarded as valid and as representing an extreme Morosauroid type. This con-

clusion is borne out by the presence of four ankylosed vertebrae in the sacrum, the subquadrate form of the coracoid, the relatively short tibia, the Morosaur-like thoracic vertebrae and the expanded blade of the scapula. Unfortunately there are parts of two skeletons represented in the type of *C. supremus*, which accounts for Cope's describing it as having twenty or more thoracic vertebrae.

There are reasons both for and against considering *Atlantosaurus* as a synonym of *Camarasaurus*. The size of the type specimens is almost identical, as is shown by the length of their respective femora. The similarity between the sacra holds so far as the number and size of the vertebrae are concerned. The one difference in evidence lies between the hollow centra described by Marsh and the solid structure of the same as stoutly maintained by Cope. The ischium of *Camarasaurus* is not known; that figured by Marsh is far from the Morosauroid type. Neither is the pituitary canal described in the skull of *Atlantosaurus* consistent with the characters which one would expect in this genus. The writer was in error in stating in a recent note on this form* that the type specimens of both genera came from the same locality. That of *Camarasaurus* was collected near Cañon City, Colorado, while the type of *Atlantosaurus* came from near Morrison, one hundred miles farther north.

Apatosaurus is clearly distinguishable from *Camarasaurus* by the narrow blade of the scapula if not by the doubtfully constant character of three coalesced vertebrae in the sacrum. With *Atlantosaurus* the sacrum forms the sole basis of comparison. If it be conceded that the primitive dinosaurian sacrum is made up of three coalesced vertebrae, we may fairly assume that the *Apatosaur* type represents merely a young specimen of *Brontosaurus*. The size of the specimen, the straight blade of the scapula, the imperfectly ossified border of both scapula and coracoid and the character of the dorsal vertebrae all bear out this conclusion.

Amphicoelias is unique in the length and slenderness of its femur. The biconcave type of caudal centrum is common to a number of Sauropod genera; but that this type of vertebra persisted throughout the thoracic series may well be questioned. The closest affinities of this genus seem to be with *Diplodocus*.

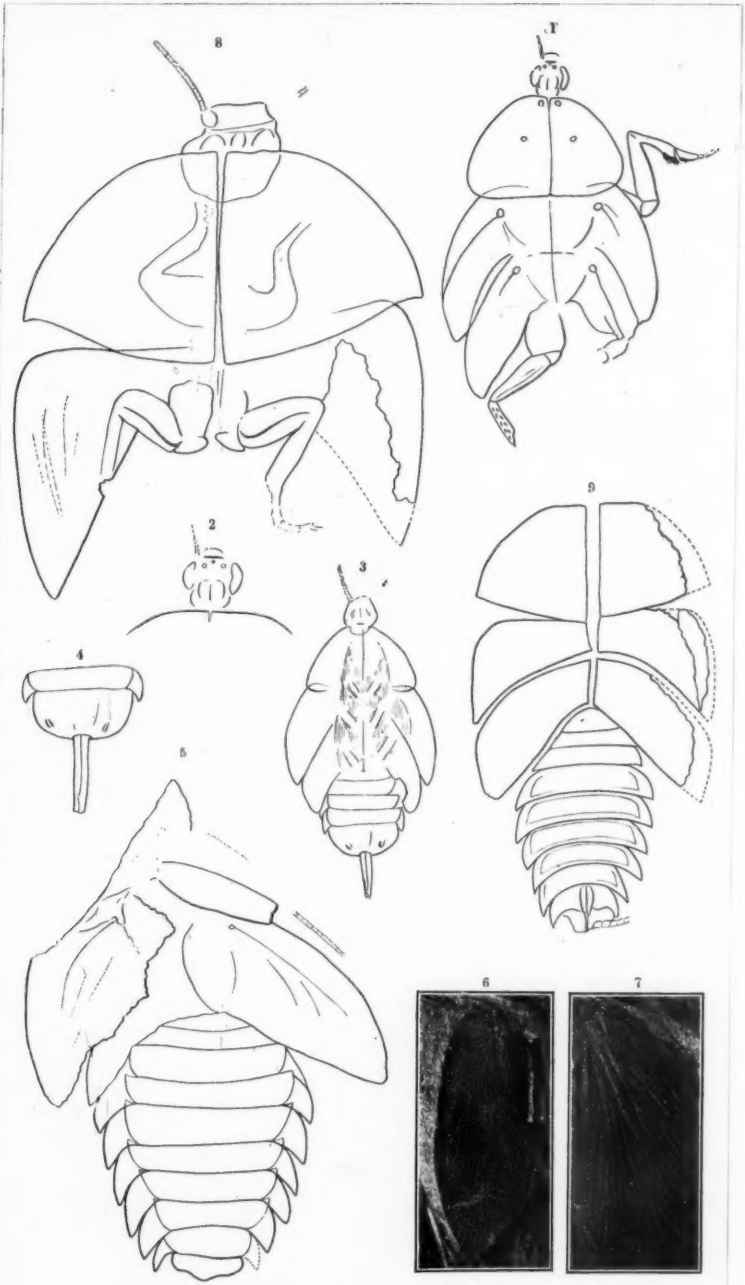
In view of this complexity of uncertain relationships, little can be said of the affinities of *Brachiosaurus*. As the humerus in the most nearly allied genera is not known, the fore leg offers no basis of comparison other than the coracoid. This bone differs from that of the type *Camarasaurus supremus* in

* Field Columbian Mus. Pub. Geol. Ser., vol. i, No. 10.

its greater length, its subovate outline, the lateral direction of its glenoid surface and the proximity of the same to the surface for sternal articulation. The femur is considerably longer, but making allowance for distortion the two could not be generically distinguished. The sacra differ in the presence of small cavities in the centra of this form. The anterior caudals of both are biconcave, their diapophyses similar, but the neural spine in *Camarasaurus*, according to Cope's measurement, is fully twice as long as that of this specimen. The essential difference in the vertebrae lies in the thoracic centra. Those of *Brachiosaurus*, as has been pointed out, range from 39 to 43 centimeters in length and from 37 to 35 centimeters in breadth. A "lumbar" vertebrae of *Camarasaurus* is described by Cope as being 17 centimeters in length and 42 in breadth. This difference alone would seem to warrant generic distinction. If *Atlantosaurus* be regarded as a valid genus, there is not enough in common between its type specimen and this one to determine their relationships. *Amphicoelias* need hardly be considered in this connection.

The further description of the sacral and presacral vertebrae of *Brachiosaurus* will be taken up in another paper. It is to be hoped that their removal from the matrix and careful study will establish the position of this genus.

Field Columbian Museum, Chicago.



NYMPHS AND WINGS OF CARBONIFEROUS COCKROACHES.

CARBONIFEROUS COCKROACH, MEGABLATTINA. × 2.

ART. XXXI.—*Some New Structural Characters of Paleozoic Cockroaches;** by E. H. SELLARDS. (With Plates VII and VIII.)

THE relatively large number of cockroaches that have been obtained from rocks of Carboniferous age indicates that these insects were extremely abundant even at that early time. The Paleozoic species, however, have been known heretofore, for the most part, from the wings alone, and of these only the more resistant front wings, or tegmina, are as a rule preserved. The more perishable organic matter of the body no doubt hastens its decay. The wings, on the other hand, are almost devoid of destructible organic matter, and at the same time their strong framework of veins makes them fairly resistant. Various contemporaneous and associated animals, such as small batrachians, spiders, and dragon-flies, doubtless fed then as now upon the bodies of insects, and some of them may have even acquired the well-known habit common to ordinary bats, modern dragon-flies, and some recent spiders, of biting off and rejecting the wings of the insects on which they prey. When detached, the wings are easily carried by currents of water, and are thus readily transported into places where permanent deposits are accumulating.

The distinctions between Paleozoic and recent cockroaches were originally based almost entirely on the framework of the front wings.† Some additional knowledge of other parts of the body has since been obtained, although acquired slowly, owing to the scarcity of favorably preserved specimens. A good deal of instructive material, however, has now accumulated, both from fuller collections from old localities and the discovery of new ones.

It is almost a decade since the appearance of Professor Scudder's last important contribution to the knowledge of Paleozoic cockroaches. In the meantime the interest in early types of insects has been greatly increased through the study of recent forms, and especially through a better understanding of the homologies of the wing veins in the different orders. The common primitive ancestor of all winged insects, or the nearest approach to such a form, is naturally to be sought in Paleozoic rocks. A return to the study of the early representatives of the cockroaches in the light of new and rich material seems, therefore, especially opportune at this time.

The writer has in preparation a study of the structure of Paleozoic cockroaches, including a description of new forms

* The present paper is for the most part taken from a more extended study of American Paleozoic cockroaches, now in preparation.

† Scudder, Mem. Boston Soc. Nat. Hist., vol. 3, pp. 23–134, 1879.

from the Coal Measures. The paper is now nearing completion, but as some time will necessarily elapse before its publication, it seems best to give in advance the results of more immediate interest.

The material on which this study is based is mostly of Coal Measure age, and is contained in the collections of the Yale University Museum, the University of Kansas Museum, the National Museum, and in the private collection of the writer. The principal localities represented are Mazon Creek, Illinois, and Lawrence, Kansas.

From the favorable preservation of the fossils contained in these large collections, it has been possible to give a more complete account of the structure of Paleozoic cockroaches than has been given heretofore. Additions have been made to a knowledge of the structure of the head, antennæ, eyes, legs, hind wings, dorsal and ventral sides of the abdomen, ovipositors, and cerci. The larval stages of several species have also been discovered.

The head is more or less completely preserved on a number of specimens. Occasionally the eyes and antennæ, which have not been previously observed, are present. The cerci vary a good deal in length in the different genera and species, and are directed either obliquely or at right angles to the body.

Nymphs.—An unusual feature of these collections is the comparative abundance of cockroaches in the immature or nymph stages, or, rather, in most cases the sheddings or moults of nymphs. That these fossils represent nymphs and not wingless adults is evident not only from the presence of the same species in different stages of development, but also from the fact that a number of them are referable to their adult genera and species, while most of them have an open slit down the thorax, indicating that the part preserved is the cast-off integument. These moults are particularly well adapted for preservation, as on the one hand they are free from the injurious effects of the organic juices of the body, and on the other escape the danger of being eaten by other animals. The chitin is hard and resistant, and yet the moults are light and like the detached wings are readily carried by currents.

The presence of nymphs at localities where the wings only of adults are found, or where the bodies are but rarely preserved, is probably to be accounted for in this way. It is extremely rare to find any part of the body of an adult insect, other than the wings, in the Lawrence Shales. Nymphs, on the contrary, as well as detached wings, are comparatively numerous. The Mazon Creek nodules contain not only the moults, but occasionally the bodies as well. Not a few of the nymphs can be identified with their proper genera and species.

Etoblattina mazona is now known in several stages, from a young age to the adult condition* (Plate VII, figures 1–4). The nymph stage of *Mylacris elongata* has also been recognized with a fair degree of certainty. As in recent Orthoptera, the young resemble the adults, growth taking place by a succession of moults. The wings appear gradually, and certain other changes similar to those seen in existing cockroaches, as the gradual rounding out of the posterior margin and angles of the pronotum can be traced.

An important part of the data regarding the structure of the body and appendages has been obtained from the nymphs, and from these also it has been possible to clear up the much misunderstood genus *Dipeltis*. This fossil, which has been variously referred to the xiphosuran and phyllopod crustaceans, is in reality an immature cockroach of the tribe Mylacridæ and probably of the genus *Mylacris*.† Through the kindness of Mr. Charles Schuchert, the type of *Dipeltis* together with the other National Museum material has been accessible for study. The contrast between fossil and matrix in the Mazon Creek nodules is often not well marked, and structural characters, which when once discovered are perfectly evident, are in danger of being at first overlooked, especially when only a few specimens are at hand for study. This has been particularly true of *Dipeltis*. The type specimen preserves, in fact, besides the prothorax and first pair of wing pads, the head, antennæ, and the first and second pairs of legs (Plate VII, figure 8). About half of the head projects in front of, and the remainder is seen in outline through, the pronotum. The left antenna, which is now more completely uncovered, is apparently joined to the head by an enlarged socket-like attachment resembling that of modern cockroaches. The segments are numerous. Those near the base are wider than long; farther out they become as long or longer than wide. The first pair of legs is seen indistinctly through the pronotum. The femora of the second pair are well preserved. They are smooth, stout, and of moderate length. The trochanters are less distinct, and only indications of the coxæ are to be seen. The tibiæ are somewhat longer than the femora. Part of the right tarsus is preserved. The first segment is comparatively long. Those following are indistinct.

The true nature of *Dipeltis* was, indeed, suspected by Gahan,

* The evidence for the generic and specific reference of the nymphs, in so far as they have been identified, will be given in the completed paper. In the case of *E. mazona*, the connection is quite satisfactorily established.

† This statement refers to the type species of the genus, *Dipeltis diplodiscus* Packard (Amer. Nat., vol. 19, p. 293, 1885; Mem. Nat. Acad. Sci., vol. iii, p. 145, 1886). The second species, *Dipeltis Carri* Schuchert (Proc. U. S. Nat. Mus., vol. 19, p. 671, 1897), from the illustration, appears to the writer to belong with *Etoblattina mazona* (cf. Plate VII, figures 1 and 3 of this paper).

who from illustrations alone compared the fossils with some coleopterous larvæ, and at the same time called attention to their striking resemblance to the nymphs of cockroaches.*

Beecher, although his results were not published, recognized *Dipeltis* as a nymph cockroach, and made plaster casts of living nymphs to show the close similarity. Over fifty specimens of nymphs cockroaches in various stages of development have now been obtained, and these have been very useful in the present study.

Structure.

Although the modern cockroaches are comparatively generalized insects, yet in important respects their Paleozoic ancestors were of a much more generalized structure, the adults retaining some characters now to be seen in the nymph stages only. The most marked changes since Paleozoic time have occurred in the front and hind wings, the abdomen, and the ovipositors.

Front Wings.—The tegmina have been thoroughly studied by Scudder and others, and compared with the front wings of living cockroaches.†

Hind Wings.—The more delicate hind wings are rarely preserved, but a considerable number have been obtained, especially from the Kansas deposits. The costal border is nearly straight, or often a little concave in the proximal half and rounded to the apex in the distal half (Plate VII, figure 7). The anal area was not so largely developed and, as Scudder has noted, did not possess the fanlike plaiting seen in almost all modern cockroaches.‡

The longitudinal fold between the cubital and anal areas, which is common to the recent cockroaches, does not seem to have occurred in any of the Paleoblattidæ. Several specimens are now known with the wings still in their natural position over the abdomen. In all of these cases, and also when found detached, the wings are always spread full width. It should be added, however, that a large undescribed species in the writer's possession, from the Upper Coal Measures, presents some indications of the doubling under of a part of the anal area, but in no instance is the fold between the cubital and anal veins. The main veins of the hind wing are more evenly developed than in most of the living forms. The first main vein, or costa, which is simple and usually marginal in the adult condition of living insects, is not only some distance from the margin, but in the more primitive Mylacridæ, and occasionally in the Blattinariæ, gives off a few superior branches. This

* Natural Science, vol. xii, p. 42, January, 1898.
† Mem. Boston Soc. Nat. Hist., vol. iii, pp. 23–134, 1879, and elsewhere.
‡ Mem. Boston Soc. Nat. Hist., vol. iii, p. 322, 1885.

character can be best observed on the two hind wings of the type specimen of *Promylacris rigida* Scudder, the matrix covering the borders having been removed for this study. The wing is strengthened as in living forms by a deep fold along the costal border. The area in front of this fold is apparently broader in the Mylacridæ than in the other tribe. Cross veins, except for the wavy reticulation of the membrane, seem to have been absent.

Abdomen.—The seventh, eighth, and ninth terga of the abdomen of Paleozoic cockroaches were evenly developed, at least in all the nymph stages, presenting in this respect a marked contrast to the common living forms in which the corresponding terga of both sexes have undergone more or less reduction. The lateral edges of the terga are well developed and project freely from the edge of the body.* The sterna of a number of specimens have been observed. They are seen either as impressions through the terga, or, the terga having been removed, are viewed directly. The seventh sternum of the female is enlarged, rounded posteriorly, and has projecting from beneath it (when viewed from the ventral side) a long ovipositor† (Plate VII, figures 3 and 4).

In the tribe Mylacridæ the sterna in front of the seventh resembles the terga in shape, being rounded in front and at the anterior corners and pointed at the posterior corners (Plate VII, figure 9). The corresponding terga of *Etoblattina*, and probably of most of the Blattinariæ (with the apparent exception of *Spiloblattina*) are, on the contrary, concave and pointed in front and rounded at the posterior border (Plate VII, figures 3 and 5).

The position of the eighth and ninth sterna of the female has not been observed. In the recent cockroaches, however, the first pair of ovipositors is attached to the eighth sternum, which is reduced and telescoped within the seventh. Such was doubtless the case, also, in the ancestors of these forms, as indicated by the ovipositor passing on the inner side of the seventh sternum. The double fold in the ventral integument, which forms the characteristic genital pouch of the modern cockroaches, seems therefore to have originated as early as the Carboniferous, although the pouch could hardly have been so perfectly developed at that time.

Ovipositor.—The ovipositor is present on several specimens. The parts of this organ in one very young individual of

* Woodward has described a nymph from the Coal Measures of Scotland, on which similar characters of the terga are noted (Geol. Mag., Decade 3, vol. iv, pp. 433–435, 1887).

† The presence of an ovipositor on Paleozoic cockroaches was first noticed by Brongniart (Comptes Rendus, Feb. 4, 1889, vol. cviii, p. 252), but has not been previously observed on American specimens.

Etoblattina mazona (to be figured later) have apparently not yet united and present a striking resemblance to the early stages in the development of the ovipositors of the Locustidæ, as figured for *Locusta* by Dewitz.* From this specimen it appears that the ovipositor is composed of probably three pairs, of which the inner is the smallest. In later stages when the three pairs have become united, the component parts are indicated by a groove down the center (Plate VII, figures 3 and 4).

New Forms.

A number of new forms have been obtained and are described in manuscript. One of these (Plate VII, figure 6) is remarkable among cockroaches of the Coal Measures, not only for the presence of numerous comparatively strong cross bars in the tegmina, but especially for the course of the anal veins, most of which end on the anal furrow. The latter character has not been previously observed on any member of the Paleoblattidæ, and the former but rarely.

A new genus from Mazon Creek is of interest because of the shape of the pronotum and the unusual size of the type species, which is by far the largest known Paleozoic cockroach. The type specimen measures not less than three and one-half inches (9^{cm}) from the anterior margin of the pronotum to the tips of the wings. The width of the body including the wings is one and one-half inches. The abdomen is long, thick, and bulky. The pronotum, unlike that of any other described Paleozoic genus, is nearly rectangular in shape, truncated in front, and enlarged and rounded at the base. The lateral margins are not quite parallel. The sides at first converge, but expand at the front border. A median line extends down the center. The wings are longer than the abdomen. The costal border of the front wings is slightly and regularly arched. The type of venation is that characteristic of the tribe Blattinariæ. The subcostal area is narrow and extends about two-thirds the length of the wing. Numerous superior veins are given off from the main stem. The radius is strong. A superior branch is given off near the base, and a few others farther out. The median area is small. The cubitus, on the other hand, is well developed, extends to near the inner angle of the wing, and gives off numerous inferior branches. The hind wings, the tips of which are seen, are apparently of about the same length as the front.

The name *Megablattina* is suggested for the genus, and *M. Beecheri* for the type species (Plate VII).

*Zeit. für wiss. Zool., vol. xxv, p. 176, pl. 12, figs. 1–11, 1875.

The fragment of a front wing from the same locality, mentioned by Scudder* "to draw attention to an unknown species remarkable for its immense size" is probably of the same species.

The large hind wing also from Mazon Creek, described and figured in the same memoir (l. c., p. 142), doubtless belongs to this genus and species. Scudder says of this wing: "A single specimen of a hind wing of enormous size differs so much from any other known that I use for it, as a convenience merely, the old generic term Blattina, as applied to fossil cockroaches in general." The estimated length, 51^{mm}, is approximately the size to be expected for the hind wing of a small individual of this species.

General Considerations.

The most important differences between the Paleozoic and recent cockroaches have already been indicated. Evolution within the group, although not rapid considering the lapse of time since the Paleozoic, has been progressive and directly in the line of increased specialization and differentiation of the organs affected. In both the front and the hind wings, there has resulted a less equal development of the main veins. There has also occurred in both wings, a migration of the main trunks of the veins toward the costal border, with a consequent reduction in the superior branches of these veins and the area occupied by them, as will be seen by comparing the more primitive Mylacridæ with the Blattinariæ. Cross veins, which rarely occur in the front wings, and so far as known are absent from the hind wings of Paleozoic forms, have since become almost universal in both wings.

Not only have both wings departed more widely from the primitive type but differentiation between the front and hind wing has increased as well.† The front wings have become, as a rule, more resistant, although there were species in the Carboniferous with wings more opaque than some of our living thin-winged species. The hind wings have developed a longitudinal fold and plaiting and an increased expanse of the anal area.‡

Important changes have occurred in the abdomen. The terga and sterna have become modified, tending towards a reduction of the number of abdominal segments. The genital pouch has been perfected, and the ovipositors have become reduced and adapted to perform a specialized function.

On the other hand, there are certain broad resemblances which should not be overlooked, implying as they do a close

*Bull. U. S. Geol. Surv., No. 124, p. 55, 1895.

†See also Scudder, Mem. Boston Soc. Nat. Hist., vol. iii, p. 320, 1885.

‡A few recent genera have developed in addition to the longitudinal fold a transverse fold of the hind wing.

genetic connection between the ancient and modern forms, the one standing in direct ancestral relation to the other. The body had essentially the same shape. The legs indicate the same habit of locomotion. The broad pronotum was as characteristic a feature of the Carboniferous as of the recent cockroach, and formed quite as secure a shelter for the small retractile head. The front wings had a similar arched form, and the anal area was as well defined.

In view of the fundamental and close relations, it seems evident that the Paleozoic and recent cockroaches constitute two nearly related and intergrading groups of a single order Orthoptera, or, more accurately, two stages in the evolution of a single phylum. Recent studies have brought to light some new structural differences separating the two stages, without, however, impairing the evidence of their interrelation. On the other hand, the discovery of a form in the Carboniferous with anal veins ending on the anal furrow and with strong cross veins tends to break down apparent differences. The very late Paleozoic and early Mesozoic species, when better known, may confidently be expected to furnish other intergrading characters.

The venation of the immature wings of modern nymph cockroaches is very similar to that of Paleozoic adults.* The modern nymphs thus present in their development an instructive recapitulation of ancestral characters.

The long ovipositor of Paleozoic cockroaches apparently indicates that a well-developed ovipositor is a primitive character of the Orthoptera, the reduction of this organ in the modern Blattidæ, like the characteristic egg case and genital pouch, being an expression of a specialized condition of the external genital organs. Some other families of the order, as the Locustidæ, are, as regards the ovipositor, less differentiated from the original type than are the cockroaches.

The plication of the anal area, so constant a feature of the hind wings of modern Orthoptera, is likewise, as Scudder maintains, a comparatively recent acquisition.

It is worthy of remark that the plication, as also the fold, of the hind wing of cockroaches developed subsequent to their differentiation as a distinct phylum. A comparatively broad anal expanse creating the need of a plication was, however, doubtless common to the early Orthoptera, but both the plication and the fold have originated independently in more than one division of the order. The same is true of cross veins. It is probable that at the time cockroaches were differentiated,

*Compare, for instance, the venation of the wing of a typical Paleozoic adult cockroach with that of recent nymphs, as given by Packard (Text Book of Entomology, p. 138, 1898; or, Comstock and Needham, Amer. Nat., vol. xxxiii, p. 574, 1899).

well-marked cross veins were entirely lacking in both wings; now, on the contrary, cross veins are numerous and not unlike those of other Orthoptera.

The plications are developed, doubtless, largely in response to mechanical principles. Mechanical need, also, has probably had an important influence in developing cross veins. The interchange of circulating fluids in the wing, tending to follow within established paths, may also, in some cases, have resulted in the origin of cross veins.

The writer is indebted to the kindness of Dr. S. W. Williston for the opportunity of studying the collection of cockroaches made for the University of Kansas Museum. Mr. Charles Schuchert has very generously supplied valuable material for study from the United States National Museum. Acknowledgments are especially due to Prof. C. E. Beecher for assistance in the study of Paleozoic cockroaches and in the preparation of the present paper.

Yale University Museum, New Haven, Conn.

EXPLANATION OF PLATES.

Plate VII.

Figures 1–4.—*Etoblattina mazona*. The first specimen figured is nearing maturity. Traces of the venation are seen, and a thickened circular area indicates the place at which the joint of the wing is to be formed. The tibiæ, as indicated, are spinous. The head, drawn enlarged in figure 2, is small. The eyes and a part of the left antenna are preserved. The second specimen, figure 3, of a younger stage, seen from the dorsal view, has the terga removed except at the edges, thus exposing the sterna. The ovipositor is seen to pass on the inner side of the enlarged seventh sternum. The obverse side of the nodule shows all ten of the terga and the cerci. From Mazon Creek, Illinois.

Figure 5.—*Etoblattina* sp. The abdomen of this species is large. In the flattened condition of the fossil the sterna show distinctly as impressions through the terga. The lateral edges of the terga are prominent. The specimen was obtained from the Upper Coal Measures, at Lawrence, Kansas.

Figure 6.—Front wing of an undescribed species from the Upper Coal Measures of Kansas. Most of the anal veins end on the anal furrow, and the wing has numerous cross veins.

Figure 7.—Hind wing from the Upper Coal Measures of Kansas.

Figure 8.—Re-illustration of the type specimen of *Mylacris* (*Dipeltis*) *diplodiscus*. The relative distinctness of some of the structures is necessarily exaggerated in the pen drawing. The head is comparatively large.

Figure 9.—Moult of a Mylacrid nymph. The sterna with their pointed posterior angles are seen as impressions through the terga. The cerci of this species stand at right angles to the axis of the body. Figures 8 and 9 represent specimens from Mazon Creek, Illinois.

Figures 1–7 are of the tribe Blattinariæ; figures 8 and 9 represent nymphs of the Mylacridæ. Figures 2 and 4 are enlarged four times; figure 8 is three times natural size; all the others are twice natural size.

Plate VIII.

Megablattina Beecheri, gen. et sp. nov. Twice natural size. From Mazon Creek, Illinois.

Art. XXXII.—*The Bath Furnace Meteorite;* by Henry A. Ward.

We are fortunate in the addition of another—the third—to the number of meteorites which have fallen to earth in the year just past and are on record.

On the evening of November 15, 1902, at about 6.45 o'clock, a brilliant meteor was seen by many persons in the States of Louisiana, Mississippi, Alabama, Georgia, Tennessee, Kentucky, and Ohio, in its progress from southwest to northeast over a course of more than six hundred miles. Its passage was simultaneously noticed by two trained observers—Professor A. H. Miller of the State College at Lexington, Kentucky, and Professor H. C. Lord of the Emerson McMillan Observatory of Columbus, Ohio. These gentlemen both secured the altitude and azimuth of the point where it appeared to burst and vanish, as seen from their rather widely separated standpoints. Calculations based upon these observations gave the approximative place of the fall—where, indeed, it had already been announced—as in Bath County, Kentucky. The detonations which immediately preceded its descent to the earth were heard over a large area in that region, most persons thinking that they were due to the explosions of nitroglycerin, which is often used in "shooting" wells in the neighboring Ragland oil fields.

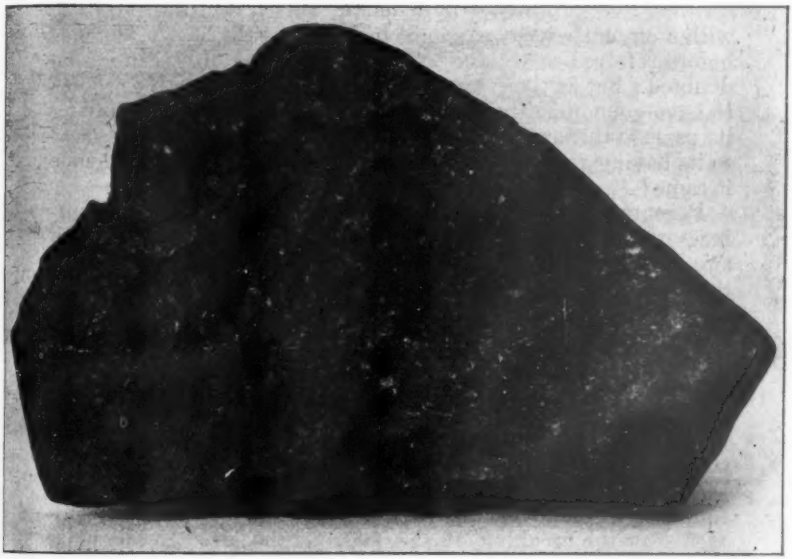
The aerolite—for such it was—came to the earth in the extreme southern part of Bath County, at an old settlement called Bath Furnace. It struck in the middle of the road, directly in front of the home of Mr. Bluford Staton. Mr. Staton and his wife at once made search for it, but on account of the darkness they failed to find it that night. The next morning, however, Mr. Staton readily discovered the meteorite lying on the surface of the ground on the side of the road, whither it had bounded. It had lost some small chippings by the collision of its fall, but was in the main quite entire.

Mr. Staton in a letter tells me: "It was dark. I saw the light and heard the report. It came through the air, whizzing like a steam-saw going through a plank. * * * The stone struck in the middle of our hard road and bounded away for about five feet to one side. The hole which it made in the road was about one foot long, nine inches wide, and five inches deep."

The aerolite is in general shape a five-sided polygon, somewhat wedge-shaped when viewed from either the side or the end aspect. Its length is 8¼ inches, height 6½ inches, width 4¾ inches. The weight of the mass is 12 lbs. 13½ ounces.

The chippings broken off in fall, if added, would doubtless make its total weight just 13 lbs. Its specific gravity is 3·48.

The stone is covered over its entire surface with a very dark —nearly black—crust. This crust, although absolutely opaque and protective, shows itself at the few fractured spots to be very thin—less than half a millimeter thick. It is dull and matte in surface appearance, with a uniform, fine granulation. This is, however, broken at frequent points by minute pimples,



interspersed with equally minute angular or slightly lengthened protuberances. None of all of these have an elevation of more than one millimeter. These pimples, where they have been rubbed, show a bright character, and are undoubtedly outside individuals of the minute points of bright iron which are sprinkled somewhat abundantly through the entire stone mass.

The inner structure of the stone, as shown in a section, is quite compact and dense, taking a good polish. It is a light gray base, blotched evenly throughout with patches of clove-brown iron oxide. Most of these are cloud-like, in indefinite contour; but a few, ranging from one to three millimeters in diameter, are round, and seem to be limited to the decomposition of a single previous iron enclosure. Very few defined chondri are detachable.

The whole mass is sprinkled liberally throughout with bright iron particles. Most of these are distributed as a bright star constellation ; but among them are scattered a small number which are from one to four millimeters in diameter, mostly of irregular, angular shape. In several instances these are broken sharply in two, and are crossed by granular troilite, fine-grained and fresh shining. One of these is a six millimeter triangle in which the three points only are of bright nickel-iron, while the balance is troilite. In two other cases, nodules, two millimeters in diameter, have a center of troilite, with a circumference of bright iron. That the brown blotches before referred to are due to the oxidation of iron cannot be doubted ; bnt as there has been no opportunity for this process to have gone on, either since the fall of the stone or during its passage through our atmosphere, the question is raised as to its having found the oxygen in the parent body from whence it came?

Pezographs, or finger-mark pittings, are visible on all surfaces of the mass, yet varying notably on different sides. On two sides they are few in number, and only dim depressions—though still unmistakable in their nature. On the other three surfaces they are frequent, and are three to five millimeters in depth, with area as large as the end of an adult human finger. Some few are independently placed, but most of them are confluent, and show the line of movement of the mass through the furrowing air. One notable gathering is curiously like the crowded tracks of three or four kittens' feet. Two of the smaller sides of the mass have a very different pitting,—that thickly crowded rain-drop appearance which is often found on a secondary crust which has formed on a fresh surface after the breaking of the mass in the air. In one place there is a furrow one and one-half inches long and two to four millimeters deep and wide, with walls of overhanging crust. So far as examination has yet been carried, this new aerolite presents no features of form or of composition which are materially different from others of its class. A careful petrographical examination may, however, reveal something of especial moment. The relation of the intruding troilite to the riven particles of nickel-iron certainly merits further investigation.

At my request, Professor Merrill of the National Museum has kindly made a couple of slides of the mass, and reports as follows : " The stone consists essentially of olivine and pyroxene, with the usual metallic sprinklings and troilite. There is present also in small quantities a completely colorless, almost isotropic mineral, which is probably maskelynite, although, if such is the case, it is a product of original crystallization and has not been altered by fusion, as suggested by Tschermak.

The mineral is in too small quantities to be determined accurately from the two sections which I have thus far prepared. The stone is chondritic, but the chondrules show no disposition to separate from the groundmass, and I am inclined to classify it with Brezina's intermediate chondrites (CI)."

The date of fall of this meteorite—November 15th—will not be overlooked. It comes as one of the Leonids whose orbit our earth cuts yearly, as it has been known for a full thousand years to do, on that date. This, as also the Saline Township, Kansas, aerolite (1898), fell on the same day of the month. These (as also Trenzano—November 12, 1856, and Werchne Tschirskaja—November 12, 1843) would seem to belong to the great Leonid stream, estimated by astronomers at many millions of miles in length, which at these dates we have cut at one of its sparse portions, picking up only stragglers in place of the millions which have shown themselves in the dates of thirty-three or thirty-four years apart, when we met with the immense bulk of the stream. It is well known, however, that in the very acme—so to call it—of these greatest of meteor-showers — 1766, 1799, 1833, 1866 — the number of meteorites which have reached our earth has not been greater than at other periods (of three days) in the year. Bath Furnace (for so we will call this stone) is still none the less suggestive as a Leonid.

Professor Farrington has already called attention (*Science*, July 11, 1902) to the fact that of the three above-mentioned meteorites which have thus far been known to fall at the time of the Leonid showers, all have had a nearly similar structure, —veined globular chondritic (CCA). We regret that Bath Furnace should not wholly coincide in this feature with the other three known Leonids (?).

Bath Furnace adds a twelfth one to the meteorites which are to the credit of the State of Kentucky. Only two of these are stones, and both of them (Cynthiana and Bath Furnace) have fallen in closely adjoining counties, only about forty miles apart. This, with an interval of twenty-six years.

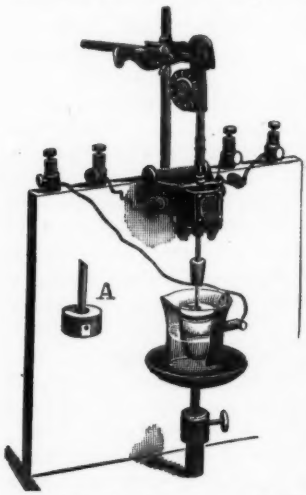
We omitted to say in its proper place in this article that this Bath Furnace meteorite passed promptly from the hands of the finder, Mr. Bluford Staton, to those of Mr. W. H. Dougherty, who in turn deposited it for sale with Professor A. M. Miller in Lexington. From him the writer duly obtained it, and has given it a place among the other 302 aerolites (stones) which make an important part of the Ward-Coonley Collection of Meteorites now on deposit and display in the American Museum of Natural History in New York.

620 Division St.,
Chicago, Ill.

ART. XXXIII.—*The Use of a Rotating Cathode in the Electrolytic Determination of the Metals;* by F. A. GOOCH and H. E. MEDWAY.

[Contributions from the Kent Chemical Laboratory of Yale University—CXV.]

THE rotating cathode has been applied usefully in the arts for the purpose of securing compact metallic deposits in electro-plating. In this case a soluble anode is employed and the electromotive force of the current is generally low. So far as we are aware, however, no attempts have been made heretofore to apply the rotating cathode in analytical separations, in which it is the object to remove the metal completely from solution. In such processes the soluble anode is not used, and the comparatively high electromotive force necessary to overcome the resistances and to throw down the metal with rapidity liberates hydrogen from the water solution simultaneously with the metal, and the consequence is the production of a deposit lacking in compactness and adhesiveness. This interference on the part of the evolved hydrogen with the regularity of deposition appears to be the chief reason why low intensity and low density of current must be used in the ordinary electrolytic processes of analysis. We have made some experiments, therefore, to see whether it is not possible to so far avoid the interfering action of hydrogen by the use of the revolving cathode as to secure with high currents and in a short time deposits sufficiently adherent and homogeneous for analytical purposes. The results, as will appear, are successful.



For a cathode we have used an ordinary 20$^{cm^3}$ platinum crucible rotating at a speed of from 600 to 800 revolutions a minute. The crucible is driven by a small, inexpensive electric motor fastened so that its shaft is vertical. Upon this shaft the crucible is fixed by pressing it over a rubber stopper bored centrally and fitted tightly on the end of the shaft (fig. A). To secure electrical connection between crucible and shaft, a narrow strip of sheet platinum is soldered to the shaft and then bent upward along the sides of the stopper, thus putting the shaft in contact with the inside of the crucible when the last

is pressed over the stopper. The shaft is made in two parts as a matter of convenience in removing the crucible and is joined, with care to make a good contact between the two pieces of shafting, by a rubber connector of sufficient thickness to prevent the crucible from wabbling when rotated.

The solution to be electrolyzed is placed in a beaker upon a small adjustable stand, so that the crucible may be dipped into the liquid to any desired depth. A platinum plate is employed as an anode, and this is connected to the positive pole of a series of four storage batteries, while the negative pole of this series is connected to the bearing in which the shaft rotates, thus allowing the current to go from the platinum plate through the solution to the crucible, up the shaft of the motor and back to the batteries.

The power to run the motor is taken from the incandescent light circuit of the street.

The first attempts were made with the deposition of copper from a solution of the sulphate, and the procedure was as follows: The solution, 50^{cm^3} in volume, was placed in a 150^{cm^3} beaker and acidulated to give better conductivity. The stand carrying the beaker was raised until the liquid covered about two-thirds of the crucible adjusted to the shaft, thus giving a cathode surface of about 30^{cm^2}. The anode was introduced and the motor started. The wires from the storage batteries were connected and the current allowed to pass through the solution. The duration of the electrolysis was varied according to the strength of current used, but in each case, after the deposit was nearly complete, the current from the batteries was shut off, the motor stopped and the sides of the beaker, the platinum anode, and the crucible were carefully washed with a fine jet of water, the motor was again started and the current allowed to pass for the remaining time.

When the deposit was complete the crucible was removed and washed, first with water, then with alcohol, and finally was dried by passing it over a flame.

Sulphuric acid [6 or 7 drops of the dilute acid—1 : 4] was generally used to acidulate the solution, since it was found that the copper was deposited in a shorter time with sulphuric than with nitric acid present. A few experiments were made in which small amounts of nitric acid were used to show that the copper could also be deposited completely in presence of this acid.

The following table show the results of a series of experiments made as described above in solutions acidulated with sulphuric acid. The standard of the solution of copper sulphate was fixed by the usual slow method of electrolytic analysis.

TABLE A.

	Copper taken. grm.	Copper found. grm.	Error. grm.	Current. amp.	N D 100.	Time.
1	0·0651	0·0652	+0·0001	0·8	2·7	25 min.
2	0·0651	0·0652	+0·0001	0·8	2·7	15 "
3	0·0651	0·0651	0·0000	1	3·3	10 "
4	0·0651	0·0649	−0·0002	1	3·3	10 "
5	0·0651	0·0658	−0·0003	1	3·3	10 "
6	0·1272	0·1272	0·0000	2·5	8·3	15 "
7	0·1272	0·1271	−0·0001	2·5	8·3	15 "
8	0·1272	0·1271	−0·0001	2·5	8·3	15 "
9	0·1272	0·1270	−0·0002	3	10	13 "
10	0·1272	0·1268	−0·0004	3	10	12 "
11	0·2548	0·2548	0·0000	3	10	20 "
12	0·2548	0·2548	0·0000	4	13·3	20 "
13	0·2548	0·2550	+0·0002	4	13·3	20 "
14	0·2548	0·2546	−0·0002	4	13·3	15 "
15	0·2548	0·2545	−0·0003	4	13·3	15 "

That the copper can be completely deposited, though more slowly, from a solution acidulated with nitric acid, is shown in the following tables. In the experiments of Table B the solution contained 6 drops of dilute [1 : 4] nitric acid, and in those of Table C 9 drops.

TABLE B.

Copper taken. grm.	Copper found. grm.	Error. grm.	Current. amp.	N D 100.	Time.
0·0651	0·0648	−0·0003	1	3·3	35 min.
0·0651	0·0652	+0·0001	0·8	2·7	30 "
0·0651	0·0650	−0·0001	0·8	2·7	25 "
0·0651	0·0649	−0·0002	1	3·3	25 "
0·0651	0·0650	−0·0001	0·8	2·7	25 "

TABLE C.

Copper taken. grm.	Copper found. grm.	Error. grm.	Current. amp.	N D 100.	Time.
0·0651	0·0652	+0·0001	1	3·3	35 min.
0·0651	0·0648	−0·0003	1	3·3	30 "
0·0651	0·0650	−0·0001	1·5	5	25 "
0·0651	0·0650	−0·0001	1·5	5	25 "
0·0651	0·0647	−0·0004	1·8	6	20 "

The rapid deposition of silver was next tried. To a 50$^{cm^3}$ solution of $AgNO_3$ was added enough potassium cyanide to dissolve the AgCN first formed. Three cm^3 of dilute sulphuric acid were run in and enough ammonia to make the solution strongly alkaline. The method of manipulation was exactly the same as in the case of copper.

The following table records the determinations made with a solution of silver nitrate standardized as the chloride.

TABLE D.

	Silver taken. grm.	Silver found. grm.	Error. grm.	Current amp.	N D 100.	Time.
1	0·0968	0·0966	−0·0002	1·8	6	15 min.
2	0·0968	0·0967	−0·0001	1·9	6·3	15 "
3	0·0968	0·0965	−0·0003	1·8	6	15 "
4	0·0968	0·0969	+0·0001	2	6·7	10 "
5	0·0968	0·0965	−0·0003	3	10	8 "
6	0·1898	0·1901	+0·0003	2·5	8·3	10 "
7	0·1898	0·1898	±0·0000	2·5	8·3	10 "
8	0·1898	0·1900	+0·0002	3·	10	10 "
9	0·1898	0·1893	−0·0005	2·5	8·3	10 "

The rapid deposition of nickel was equally successful. Nickel-ammonium sulphate was dissolved in 25$^{cm^3}$ of water and 20$^{cm^3}$ of strong ammonia were added. In this liquid about a gram of ammonium sulphate was dissolved and the solution was treated in the same manner as in the preceding experiments upon copper and silver. It should be especially noted, however, that the solution must be kept within the limits of volume indicated above, as further dilution lengthens the time necessary for complete deposition.

TABLE E.

	Nickel taken. grm.	Nickel taken. grm.	Error. grm.	Current. amp.	N D 100.	Time.
1	0·0954	0·0954	0·0000	1·5	5	30 min.
2	0·0954	0·0953	−0·0001	3	10	25 "
3	0·0954	0·0956	+0·0002	3	10	25 "
4	0·0954	0·0953	−0·0001	3·5	11·7	20 "
5	0·0954	0·0955	+0·0001	3·5	11·7	20 "
6	0·1738	0·1736	−0·0002	3·5	11·7	25 "
7	0·1738	0·1740	+0·0002	3·5	11·7	25 "
8	0·1738	0·1740	+0·0002	4	13·3	25 "
9	0·1738	0·1737	−0·0001	4	13·3	25 "
10	0·1738	0·1738	0·0000	4	13·3	25 "

From these results it is plain that nickel, like copper and silver, may be deposited with rapidity and completeness.

The metallic deposits of these metals obtained by means of the revolving cathode are sufficiently coherent and compact to permit accurate manipulation and weighing even when the current density on the cathode is very considerable and variable within wide limits. Other metals have been found to behave similarly and the results of further experimentation will be described later.

The advantages of this rotating cathode in analytical operations are obvious: the process as described is rapid, exact, and very simple. The apparatus required, moreover, is inexpensive, and, if it is desired to make many determinations simultaneously, a single motor may be made to drive a running belt over any reasonable number of rotating shafts.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Qualitative Separation of Arsenic, Antimony and Tin.*—James Walker describes the following method for the analysis of this group: The sulphides are dissolved in caustic soda and the solution is boiled with sodium peroxide. This produces sodium stannate, arsenate and antimonate. An excess of ammonium chloride is then added, and the liquid is boiled. This treatment precipitates all the tin as stannic hydroxide, and, although the precipitate may contain a little antimony, the separation answers for qualitative purposes.

In separating the sulphides under consideration from the sulphides of the copper group by the use of sodium hydroxide, it is necessary to add a few drops of yellow ammonium sulphide in order that stannous sulphide may readily dissolve. It is to be noticed, also, that mercuric sulphide is soluble in the solution, but this is precipitated as such when the other sulphides are oxidized by boiling with sodium peroxide.

The presence of tin is confirmed by dissolving the stannic hydroxide in concentrated hydrochloric acid, reducing to stannous chloride by boiling with metallic iron, and testing with mercuric chloride, or also with hydrogen sulphide.

To detect antimony and arsenic it is recommended to acidify the filtrate from the stannic hydroxide, to warm until oxygen ceases to be evolved, then to cool and pass in a rapid stream of hydrogen sulphide. This treatment precipitates antimonic sulphide, which is filtered off. The resulting filtrate is then treated with a few drops of sodium thiosulphate solution and warmed until a precipitate begins to form. This may be sulphur alone, or also arsenious sulphide. The precipitation of arsenic is then made or completed by passing hydrogen sulphide.—*Jour. Chem. Soc.*, lxxiii, 184. H. L. W.

2. *Arsenic Pentachloride.*—Although phosphorus and antimony pentachlorides are well known, all the numerous attempts to prepare the pentachloride of arsenic have failed heretofore. The apparent non-existence of this compound is considered remarkable on account of the intermediate position of arsenic in its relations to phosphorus and antimony. Baskerville and Bennett now believe that they have succeeded in preparing this much-sought compound. They placed arsenic trichloride in a test-tube surrounded by solid carbon dioxide, then led in chlorine. The trichloride, which had solidified at the low temperature used, assumed a greenish yellow color and became liquid, and the liquid increased in bulk, since the chlorine was liquefied. By allowing "the excess" of chlorine to distil off at a temperature two or three degrees above the boiling point of chlorine ($-33{\cdot}6°$), a residual liquid was obtained, in one case at least, which had a

composition approaching that required for the supposed compound $AsCl_5$. It may be observed that there is very slight evidence here that the liquid was a definite compound rather than a solution of $AsCl_3$ in liquid chlorine, for there is no doubt that the boiling point of chlorine would be raised appreciably by the presence of a large amount of a substance in solution. However, the authors state that the product after being dissolved in absolute ether at $-30°$, gave yellow prisms when the solution was chilled several degrees, and that a special preparation made in a sealed tube formed beautiful yellow crystals at -38 or $40°$. These facts furnish, perhaps, some evidence of the existence of the pentachloride, but it seems unfortunate that the crystals were not analyzed.—*Jour. Amer. Chem. Soc.*, Nov., 1902. H. L. W.

3. *Electrolytic Peroxides of Lead, Nickel and Bismuth.*—Hollard finds that when lead is deposited in the form of a higher oxide by the electrolysis of nitric acid solutions of lead nitrate, the deposit does not consist of pure lead dioxide as has been supposed, but that it contains less lead than the amount corresponding to this compound (which contains 86·6 per cent of lead). The variation is but slight with large deposits, such as one containing 10^g of lead, but it is much greater with small quantities. When about $\cdot 01^g$ of lead was present, the deposit contained 74 per cent of lead, and as the lead was increased in quantity the amount of lead in the deposit gradually increased to 86·1 per cent for 10^g. The explanation is advanced that higher oxides than PbO_2 are formed, but this point does not appear to be proven.

A deposit of nickel oxide was obtained by electrolyzing an alkaline pyrophosphate solution containing chromic acid. The weight of the deposit corresponded to the formula NiO_4 on the assumption that nothing but nickel and oxygen was present, but in this case also the point was not proven. An anodic deposit from bismuth sulphate in nitric acid indicated the improbable formula Bi_2O_7.—*Comptes Rendus*, cxxxvi, 229. H. L. W.

4. *A Peculiar Double Salt of Silver Iodide.*—Strömholm has observed the remarkable fact that when solutions of tetraethyl-ammonium iodide are treated with silver salts, the precipitates are not yellow but white. This is caused by the formation of a double salt $N(C_2H_5)_4I{\cdot}2AgI$, which is distinguished from all the previously known double salts of the silver halides, not only by representing a new type, but by its great stability in dilute solutions. Such double salts are usually stable only in contact with very concentrated solutions of the soluble halides, hence the tetraethyl-ammonium-silver iodide resembles the double cyanides in its stability, although, unlike them, it is insoluble. The compound under consideration can be washed with a $1\frac{1}{2}$ per cent solution of $N(C_2H_5)_4I$, but it is decomposed in contact with boiling water with formation of yellow silver iodide. It is decomposed also by warming with an excess of silver nitrate solution, with the formation of the same yellow product. The double salt is entirely stable when exposed to daylight.—*Berichte*, xxxvi, 142.

H. L. W.

5. *Method for the Determination of Carbon in Steel.*—As a solvent for steel when carbon is to be determined, G. W. SARGENT recommends the use of potassium ferric chloride, since it has the advantage of being less strongly colored than the usual reagent, potassium cupric chloride. A solution containing 267^{g} of commercial, chemically pure ferric chloride and $130{\cdot}7^{g}$ of potassium chloride in a liter is equivalent to the cupric solution commonly used. It should contain 1^{cc} of free hydrochloric acid in 225^{cc} in order to prevent the formation of basic ferric salts, but a greater quantity of acid than this is liable to cause the evolution of hydrogen and hydrocarbons. The reaction corresponds to the equation,

$$2FeCl_3 + Fe = 3FeCl_2.$$

The liquid which has been used can be brought to its original condition by chlorinating and adding the proper amount of potassium chloride.—*Jour. Amer. Chem. Soc.*, xxiv, 1076. H. L. W.

6. *Physical Chemistry for Physicians and Biologists;* by Dr. ERNST COHEN. Authorized Translation by MARTIN H. FISCHER, M.D. 8vo, pp. 343. New York, 1903. Henry Holt and Company.—This book is made up of fifteen lectures by a physical chemist, which serve as a satisfactory introduction to the subject in general, and which deal especially with the application of this science to medical and biological problems. The topics discussed are well chosen, the explanations are clear and satisfactory, and it is believed that the book will be very interesting and useful to those for whom it is intended. H. L. W.

7. *The Bunsen Flame of Radium.*—F. Giesel has shown that a very small amount of radium bromide gives a characteristic color to the Bunsen flame. He describes the spectrum as one consisting of two red bands and a bright blue line. He also saw feeble lines in the violet. C. RUNGE and J. PRECHT have investigated this spectrum with the aid of a Rowland grating of one meter radius. They found the spectral lines very transitory. The line in the blue at wave length 4826 remained the longest. It seemed of the same character as the barium line 5536; the strontium line 4607, and the calcium line 4226. A table of wave lengths is appended to their article.—*Ann. der Physik*, No. 3, 1903, pp. 655–657. J. T.

8. *Interference of Light by means of a Plane-parallel Plate.*—O. LUMMER and E. GEHRCKE discuss the various methods in interference spectroscopy and describe a method which resembles Michelson's echelon spectroscope; but which the authors think is simpler. It consists in the use of only one plane parallel plate. The method shows that many lines considered as consisting of a few components are far more complicated than has generally been supposed. The authors remark that Michelson's value for the red cadmium line $\lambda = 643{,}847$ cannot be considered a definite wave length measured to the given decimal place; nor a certain mean wave length of a continuous region; it is rather the center of gravity, so to speak, of a complicated system of

lines. The authors indicate that the varying results of different observers result from the use of different methods of observation rather than from the deficiencies of the apparatus.—*Ann. der Physik*, No. 3, 1903, pp. 457–478. J. T.

9. *Electricity carried by a Gaseous Ion.*—Prof. J. J. THOMSON has repeated his determination of this quantity by means of radium and more accurate apparatus. The number $3{\cdot}4\times10^{-10}$ was found as the charge in electrostatic units of the gaseous ion. This is about half the number $6{\cdot}5\times10^{-10}$ found in the author's previous experiments. The author attributes the difference to the failure of the first experiments to catch the positive atoms, thus making the value of n, the number of ions per c.c., little more than half the true value, while it made the value of e, the charge in electrostatic measure on an ion, twice as great as it ought to have been.—*Phil. Mag.*, March, 1903, pp. 346–365. J. T.

10. *Potential Distribution in the dark Cathode Space.*—A. WEHNELT finds that there are no potential maxima or minima in this space. The results, therefore, of W. P. Graham arise from faults of method of investigation. The author finds that Prof. Shuster's interpolation formula representing the run of potential is not confirmed by his investigation.—*Ann. der Physik*, No. 3, 1903, pp. 542–580. J. T.

11. *Mechanics, Molecular Physics and Heat;* by R. A. MILLIKAN. 242 pp. (Chicago: Scott, Foresman and Co.)—This is a treatise adapted to a twelve weeks' college course, in which the author has endeavored to combine a class-room text and laboratory manual. A certain number of well chosen laboratory exercises are made the basis of the course, whose object is to teach thoroughly a few fundamental principles rather than to present a large mass of facts. The theoretical discussions are generally sharp and clear and are followed by directions for the laboratory exercises, with illustrative problems. Another volume, for the second third of the year, covering the subjects of Electricity, Light and Sound, is to follow. This plan necessitates, for the third part of the year, a course of demonstration lectures on such parts of the subject as are more suitable to lecture than to laboratory presentation. D. A. K.

12. *American Physical Society.*—The American Physical Society is now joined with the Institution of Electrical Engineers and the Physical Society of London in the direction of the publication of "Science Abstracts" (edited by G. W. de Tunzelmann, London), and has elected Professor E. H. Hall of Harvard University as its representative on the publishing committee. In consequence of this arrangement, "abstracts" dealing with physics will in future be received by all members of the American Physical Society.

13. *The A B C of Photo-Micrography;* by W. H. WALMSLEY, 155 pp., 29 photo-micrographs. New York: Tennant & Ward.—Mr. Walmsley is a recognized authority in the photo-micrographic world and his little manual is a welcome addition to the scientist's outfit. The subject is treated plainly yet thoroughly and comprehensively.

II. Geology and Natural History.

1. *United States Geological Survey.*—The following publications have recently been received:

Twenty-Second Annual Report, 1900–1. Pt. IV. Hydrography. 669 pp. 65 pls., 244 figs.—Mr. Newell, chief of the Division of Hydrography, reports on the progress of stream measurements throughout the United States (pp. 9–506). A. P. Davis's paper on the Hydrography of the American Isthmus presents the facts regarding the physiography, rainfall, drainage, etc, along the lines of the Nicaragua and Panama canals. The High Plains and their Utilization (pp. 637–667), by Willard D. Johnson, is the conclusion of a valuable contribution to physiography begun in the twenty-first annual report.

Masontown-Uniontown Folio, Pennsylvania, No. 82; by M. R. Campbell. 21 pp. with maps and sections.—The first of a series of new maps of the Pittsburg Coal District shows marked improvement over previous work. It is probably the most accurate piece of geologic mapping yet published. The economic geology includes coal, oil and clays; the well-known abandoned channels of this region are explained as consequences of local ice dams.

Ditney Folio, Indiana, No. 84; by M. L. Fuller and G. H. Ashley. 8 pp. with maps and sections.—The Ditney area is part of the Illinois-Indiana coal basin. It is a region of horizontal rocks moderately dissected and glaciated.

Ellensburg Folio, No. 86; by Geo. Otis Smith (Washington, D. C., 1903, 7 pp. text).—The area described geologically in this folio consists mainly of basaltic outflows of Neocene age which cover the older rocks. These have been in part eroded and upon them have been laid down gravels, fluviatile deposits, alluvium, etc. of Neocene and Pleistocene time, with andesitic outflows of the latter period. The mapping is an excellent piece of careful work and the descriptive text is clear and readable. In the field work Dr. Smith was assisted by Mr. F. C. Calkins.

L. V. P.

Bulletin No. 200. Reconnaissance of the Borax Deposits of Death Valley and Mohave Desert; by M. R. Campbell. 22 pp., 1 map.—The borax of the Death Valley region occurs in a regular stratum interbedded with semi-indurated sands and clays. The mines at Borate are the chief producers of borax and boracic acid in the United States.

Bulletin No. 201. Results of Primary Triangulation and Primary Traverse (1901–02); by Messrs. Wilson, Renshawe, Douglas and Goode.

Bulletin No. 202. Gold and Silver in Shales from Western Kansas; by Waldemar Lindgren. 19 pp.—In spite of published accounts to the contrary, Dr. Lindgren shows that the Kansas shales do not contain gold or silver in paying quantities.

Bulletin No 204. Fossil Flora of the John Day Basin,

Oregon; by FRANK HALL KNOWLTON. 113 pp., xvii plates.— The fossil flora of the John Day Basin comprises 150 forms, distributed among 37 natural families and the anomalous group of Phyllites. Of the 150 forms, 24 are not specifically named, and 44 species and 1 variety are described as new. The previously known species number 81. These plants are from several different horizons, the oldest being regarded as of Lower Eocene, and the youngest of Upper Miocene age. It is concluded that the conditions which prevailed in the John Day Basin area during Tertiary times extended also into central Washington, northwestern Idaho, and western Oregon, and that the flora was distinctly a hard wood one containing many oaks, willows and maples, as in much of the area east of the Mississippi River at the present time. Many of the John Day species are closely related to forms now living in the Eastern States. A rather large-leaved *Gingko* appears to have been present in the uppermost beds. Very few ferns are present.

The writer does not attempt any special consideration of the comparative climatic conditions in the great Tertiary lake basins on the eastern flanks of the Rockies. They may in my opinion have been somewhat or even markedly warmer than the western slopes, especially in Eocene times, though not of course in the later Tertiary. G. R. W.

DIVISION OF HYDROLOGY. — A Division of Hydrology has recently been organized in the hydrographic branch of the United States Geological Survey. The work of this division will include the gathering and filing of well records of all kinds, the study of artesian and other problems relating to underground waters, and the investigation of the stratigraphy of the water-bearing and associated rocks. In addition to the gathering of statistics relating to the flow, cost, etc., of the wells, it is hoped in the future to give especial attention to the geologic features which govern or which are related in any way to the supply of water.

The division will be sub-divided into two sections, the first embracing the Gulf and Mississippi River States and the States to the east, and the second embracing the remaining States and Territories. The charge of each section has been assigned to a geologist, the western section to Mr. N. H. Darton, and the eastern to Mr. M. L. Fuller. The office details are in charge of Mr. Fuller.

2. *Report of the State Geologist of Vermont for 1901–1902;* by GEORGE H. PERKINS, State Geologist. 191 pp., 62 plates.— The first 30 pages of the report contains a brief account of the history of geological survey work in the State with reprints of articles first published elsewhere on Zadock Thompson and Augustus Wing, former state geologists. The body of the report contains papers by the State Geologist on mining industries and on the Geology of Grand Isle; by G. I. Finley on the Granite Area of Barre; by C. F. Richardson on the Terranes of

Orange County; and by H. W. Shimer on Petrographic Descriptions of the Dikes of Grand Isle. The paper on Grand Isle geology is a valuable contribution to the structural analysis of the Ordovician rocks of the region covered. The revival of the name Champlanian, for Lower Silurian or Ordovician, is unfortunate, especially in a paper in which Champlain clay is used seven times in another sense. H. S. W.

3. *A Report on the Geology of Louisiana*, Pt. VI; by GILBERT D. HARRIS, Geologist-in-charge, for the field seasons 1900–1901–1902. 288 pp., 10 plates, 7 figs. State Experiment Station, Baton-Rouge, La., Wm. C. Stubbs, Director.—The Report consists of a series of papers on various geological problems of the State: I. The Geology of the Mississippi Embayment, G. D. Harris. II. The Salines of North Louisiana. The geological age of the salt-bearing beds is Cretaceous for the salt-bearing rock of North Louisiana and Texas. III. The Geography and Geology of the Sabine River. The author has worked out a complete geological section for the region cut by the river. IV. Notes on the Geology along the Ouachita. Papers II, III, IV are by A. C. Veitch. V. Improvements in Louisiana Cartography; VI, Subterranean Waters of Louisiana; VII, Tides in the Rigolets, and VIII, Oil in Louisiana, by R. T. Harris. The horizon of this oil is not certainly fixed, though some of the wells issue from beds as late as Miocene. H. S. W.

4. *Tables of Minerals;* by S. L. PENFIELD. 77 pp. Sold by the Yale Coöperative Association, New Haven.—This pamphlet was issued to serve as a guide and reference book to accompany lectures on crystallography and descriptive mineralogy. The minerals are arranged in the tables as follows: I. According to the six systems of crystallization and their prominent subdivisions, the minerals of each subdivision being arranged in accordance with the chemical classification adopted by Dana. II. According to the elements, emphasis being given to minerals which are important from an economic standpoint. Short descriptions are added to the lists stating the uses of the minerals and brief summaries are given of the amount and value of their production. III. With reference to geological occurrence and association, as rock-making minerals, vein minerals, etc.

The minerals are given three ranks according to their relative importance, which is indicated in the tables by the type used in printing the names of the species. Accompanying the names of the minerals their chemical formulas are given and also numbers corresponding to the pages in Dana's Text-Book of Mineralogy and System of Mineralogy, on which descriptions of the species may be found. W. E. F.

5. *Ueber Urausscheidungen in rheinischen Basalten;* von F. ZIRKEL. (Bd. xxviii, Abh. mat. phys. Klasse d. K. Säch. Ges. d. Wiss., No. III, 1903, pp. 103–198.)—The basalts of the Rhine district have long been known for the many interesting inclusions which they contain, single minerals, such as olivine in masses,

sapphire crystals, etc. or aggregates of numbers of minerals associated together. These have been studied in great detail by Professor Zirkel, who presents in addition suggestive views regarding their origin and relation to igneous rocks. Since the appearance of the well-known work of LACROIX, this is without doubt the most important contribution to the literature of this subject. L. V. P.

6. *Princeton University Expedition to Patagonia.*—The first volume of the reports of this important expedition, issued in handsome quarto form with many plates under the J. Pierpont Morgan Publication fund, contains a narrative of the expeditions and an essay on the Geography of Southern Patagonia by J. B. HATCHER. The volume is dedicated to O. C. Marsh. The narrative gives an interesting account, though occasionally in overelaborate phrasing, of three arduous journeys made by Hatcher and an assistant. Although much was discovered in the way of geological structure and although large collections of fossils were made, it is evident that a great amount of further study is needed in this little known region: the narrative must indeed prove inspiring to young men of good training and active habit. The physical features of the region are well described: the great shingle formation with which the plains are covered is explained as the littoral deposit of a retreating sea supplied with abundant boulders and cobbles from the glaciers and rivers of the Andes; the terraces of the plains are sea-cliffs carved during halts in the emergence of the land; the great transverse valleys were eroded by normal river action before the time of the depression in which the shingle formation was spread out, for they are blanketed with the shingle, and the terraces turn inland along the valley sides. The Straits of Magellan are explained as the southernmost of these transverse valleys, not yet fully emerged. The great piedmont lakes are accounted for by earth movements, little value being given to glacial erosion; and although extensive moraines are found east of the lakes, these deposits do not seem to be of great thickness. Two of the lakes, Viedma and Argentino, are drained by Santa Cruz river, the only large perennial river of the region. The other large lakes are discharged to the Pacific, through deep gorges in the Andes, for the most part unexplored. A chapter on the Tehuelche Indian tells of their abandoning the bow and arrow for the bolas since the introduction of horses by the Spaniards. W. M. D.

7. *Argentino-Chilian Boundary: Argentine Evidence.* Five 4to vols. (London, Clowes, 1900.)—The "brief" presented in five large volumes by the Argentine boundary commission under a title too long to be quoted, to the British Arbitration tribunal, whose decision has lately been rendered, deserves mention as an important contribution to Andean geography. It contains a large number of maps and many excellent photographs, besides an elaborate descriptive text, and must for many years serve as the standard general description of the region. Special attention

is naturally given to the contrast between the well defined lofty Andean chain, through which most of the eastern piedmont lakes are drained in deep canyons, and the indistinct continental divide on the plains east of the lakes, inasmuch as it was from the assumed coincidence of the divide and the mountain crest that the misunderstanding between Chile and Argentina arose.

W. M. D.

8. *The Bermuda Islands: Their Scenery, Climate, Productions, Physiography, Natural History, and Geology; with sketches of their Early History and the Changes Due to Man.* by ADDISON E. VERRILL. 558 pages, 8vo; 292 cuts in text; 40 plates. March, 1903.—This work is the author's reprint of part ii of vol. xi (centennial volume) of the Trans. Conn. Acad. of Arts and Sciences, with the addition of three pages of illustrations and a preface. It contains a comprehensive account of the islands, from personal observation and studies, which will be of great use both to casual visitors and to scientific students. The work is divided into forty-one chapters, besides various special subjects treated in the Addenda. It includes about equal parts of descriptive matter on physiography, including meteorology; history; botany; and zoology, chiefly relating to the land fauna. The climate, as related to the use of the islands as a health resort, receives considerable attention, as well as the history of former epidemics of imported diseases. The changes in the fauna and flora effected by man are very fully discussed, as well as the original flora and fauna. The insects of Bermuda have hitherto received very scant attention, only very meager lists of names, without descriptions or references to habits, having been given by writers. In this work the number of species is increased to 265, or more than double those previously recorded, and most of these are described and figured, especially those injurious to the crops. Attention is called to the remarkably small number of insects, and to the fact that nearly all have evidently been introduced by man since the settlement. Only three new species of insects are described: the large cicada (*C. Bermudiana* V.); a remarkable new genus of Psocids (*Heteropsocus dispar* V.), in which the male is fully winged, while the female has the hind wings abortive; and a geometrid moth (*Alcis Verrillata* Dyar). Chapters are also devoted to the whales, birds, sea-turtles, historical fishes, spiders, myriapods, terrestrial crustacea, earthworms, etc., but the marine invertebrates are mostly reserved for another volume.

The more interesting events in the early history and discovery of the islands are recorded, with quotations from the earliest visitors and settlers as to the original condition of the islands and the remarkable events of the early days. The history of the ancient ruined forts, situated on the deserted islands, is fully discussed, with illustrations of the ruins. The forty half-tone plates are excellent reproductions of photographs, most of which were made specially for this work by Mr. A. H. Verrill and other mem-

bers of Professor Verrill's parties. Many illustrate the more interesting views of scenery and peculiar rock-formations; others show unusual or interesting forms of vegetation. Perhaps the most remarkable are the reproductions of photographs (made from life) of the tropic-bird and other birds, and of various insects, including several butterflies, just in the act of taking their first flight after emerging from the pupa-cases on which they rest, and showing, at the same time, the larvæ feeding on their natural food-plants. One of the plates is an excellent likeness, with autograph, of the late Governor Lefroy, the only governor who has ever shown much interest in the natural history and archives of the islands, and who published several works on the botany and early history of the islands. In the Addenda, among other subjects, some of the early witchcraft trials are given. They were much like those of Salem, Mass., though about forty years earlier.

9. *Zoology of the Bermudas.* Vol. I, 427 pp., 8vo, 45 plates, many cuts. New Haven, Conn., March, 1903; by A. E. VERRILL and associates.—This volume consists of reprints of fifteen principal articles, and some minor ones, relating to the zoölogy and geology of the Bermudas, which have been published during the past two years in the Trans. Conn. Acad. and elsewhere. They all relate to the collections made by the expeditions to the islands from Yale University, under the supervision of Professor Verrill. Among the subjects treated are the corals, actiniæ, annelids, echinoderms, mollusca, isopods, decapods, bryozoa, planarians, spiders, the cahow and other birds, etc. Most of these articles are freely illustrated and many new forms are described in several of them.

10. *West Indian Madreporarian Polyps*; by J. E. DUERDEN. 4to, 197 pp., 25 plates. Memoirs Nat. Acad. Sciences, VIII, 7th Mem.—Mr. Duerden, while residing several years in Jamaica, took good advantage of his opportunities to study the soft parts of a considerable variety of reef-corals that occur there. In these memoirs he gives numerous details concerning their anatomy and histology, well illustrated by numerous figures. This work adds greatly to our knowledge of the animals of the Madreporaria, as a whole, as well as to the particular forms studied, which include species of *Madrepora* (*Acropora*), *Porites*, *Siderastræa*, *Solenastræa*, *Orbicella*, *Cladocora*, *Manicina*, *Mæandrina* (*Mæandra*), *Favia*, *Isophyllia* (*Mussa*), *Oculina*, etc. An abstract of his results would be quite beyond the limits of a review at this time. It is, perhaps, unfortunate that the author has not adopted the revised nomenclature of the genera and species treated, but in general there can be no doubt about the identity of the species studied. However, it seems to me almost certain that his "*Agaricia fragilis*" is not the species that properly bears that name, which is always pedicellate, while his form is partially encrusting. A. E. V.

11. *The Coral Reefs of the Tropical Pacific*; by ALEXANDER

AGASSIZ. Memoirs of the Mus. Comp. Zoology, Cambridge, Mass., vol. xxviii, iv, 4to, in five parts, 236 plates.—This extensive work is the result of the scientfic explorations carried on by Mr. Agassiz in the steamer Albatross, August, 1899, to March, 1900. The numerous illustrations are mostly heliotype reproductions of photographs made by members of the party. There are also numerous charts of the regions visited, and two colored plates of coral islands drawn by Mr. J. H. Emerton, from sketches by Mr. Agassiz and Dr. Mayer. The plates show very perfectly the character and structure of the very numerous reefs and islands visited, which include the Marquesas, Tuamotu, Society, Tonga, Fiji, Gilbert, Marshall, Caroline, and other groups of islands. Mr. Agassiz finds that there is far more diversity in the structure and modes of formation of these islands than Darwin, Dana, and other former writers supposed. In general, his observations do not sustain the current theories of the enormous thickness of the coral reefs, due to continuous upward growth during long periods of subsidence. This great work must long remain a standard treatise on the geology and physiography of the Pacific coral islands. A. E. V.

12. *Index Animalium;* by C. DAVIES SHERBORN. 1195 pp. Cambridge University Press. (New York: The Macmillan Company.)—'The objects of this work are (*a*) to provide zoologists with a complete list of all the generic and specific names that have been applied by authors to animals both fossil and recent since 1758; (*b*) to give an exact date for each page quotation; (*c*) to give a quotation for each reference sufficiently exact to be intelligible alike to the specialist and to the layman.' The present volume includes the years 1758–1800. Mr. Sherborn has shown remarkable patience and tireless effort in amassing the facts essential to such a book.

13. *Andrews's Botany all the Year Round;* by E. F. ANDREWS. 8vo, 302 pp. (American Book Company, New York, Cincinnati, and Chicago.)—This book is admirably adapted for botanical work in the average high school, and requires no expensive equipment. The lessons are so arranged that each subject is taken up at the time of year when the material for it is most abundant.

OBITUARY.

Rear-Admiral WILLIAM HARKNESS, U.S.N. (retired), the eminent astronomer, president of the American Association for the Advancement of Science in 1893, died on February 28, of typhoid fever, in his sixty-sixth year.

Dynamical and Structural Geology

A few of the more important and showy forms recently received in this department are:

ORBICULAR GRANITE.

Kortfors, Sweden. Of this interesting rock we have but three specimens on hand. The concretions are mainly hornblende imbedded in a coarse-grained light colored granite, making a strong contrast between the matrix and the concretions, the latter being from 2½ to 3 inches in diameter; polished slab 8 x 19 in. in diameter, $20.00; larger, $22.00 and $30.00.

Kangasniemi, Finland. In this rock the concretions are light colored surrounded by bands of hornblende, the compactness of the concretion forming a strong contrast to the coarse crystalline structure of the matrix. The concretions range from 4 to 6 inches in diameter. Specimens from $6.00 to $30.00.

Quonochontaug, Rhode Island. This is the only Orbicular Granite we have ever seen from America. The concretions are mainly hornblende with granite centers intermediate in color between the above two, and average from 1 to 2¾ inches in diameter; polished slices from $6.00 to $13.00.

Orbicular Diorite (Napoleonite, Corsite). This well-known rock is now quite rare. The concretions, consisting of anorthite, hornblende and some quartz, are comparatively uniform in size, averaging about 1½ inches in diameter; magnificently polished slabs of this rare rock from $4.00 to $15.00.

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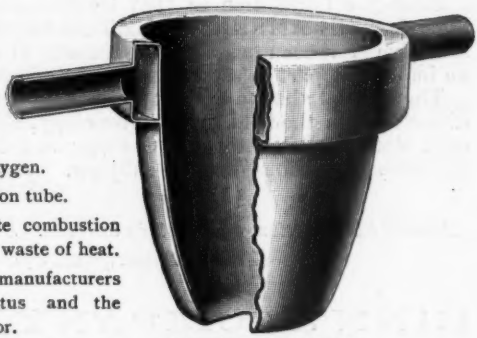

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